

Investigating the Role of Labelling and Packaging on Medication Error

by

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## Abstract

Medication administration error contributes to deaths and injury in hospitals, especially in the area of anaesthesia. Labelling and packaging contribute to medication error. The current study examined the role of labelling and packaging in medication error and compared medically trained and medically naive participants.

Using eye-tracking equipment, Study 1A investigated the distribution of fixations across 32 pre-existing medication labels and packages. Both groups of participants fixated less on the dose and top of medications than on the name and 'other' features. Both medical experience and packaging type influenced on which label areas participants fixated. Medical participants fixated on dose more than control participants; there were no other differences between groups.

In Study 1B participants viewed a target medication, they were then asked whether it was present in an array. The target was present in 50% of arrays. Distractors varied in similarity to the target. Signal detection theory analysis of discriminability through  $d'$  revealed that medical participants were significantly better than control participants at discriminating whether or not the target was in the array. Bias analyses through  $C$  revealed that there was no difference between the biases of the two groups. Both groups of participants adopted a liberal criterion which increased the occurrence of false alarms. Across all trials, participants were most likely to select a distractor that differed only in the dose of the medication.

Divided attention can increase medication error rates, therefore Study 1C utilised the same procedure as Study 1B and added a divided attention task. During the divided attention task participants saw a string of either five or seven letters and were later asked to recall one of the letters. Both groups of participants recalled fewer letters in the seven-letter compared to five-letter condition. There was no difference in the overall performance of the two groups on the divided attention task. Both groups showed a significant reduction in discriminability under the seven- compared to five-letter divided attention condition. Medical participants had significantly higher discriminability indices than control participants. Both groups of participants adopted a liberal criterion, however control participants were more biased than medical professionals. Control participants displayed an increase in bias in the seven-letter, compared to five-letter condition; the bias of medical participants was not influenced by the divided attention task. As in Study 1B, participants were most likely to select a distractor that differed only in the dose of the medication.

Overall, participants were biased towards responding that the target was present in the array. This type of bias leads to an increase in the misidentification of a medication. In an applied medical setting this could result in the incorrect administration of a medication. Furthermore, participants looked less at the dose of the medication and then made errors that reflected a failure to attend to dose. Therefore, the presentation of the dose of a medication should be the focus of strategies to reduce error by improving medication labels.

## **Chapter One: General Introduction**

In late 1991 a patient died due to the administration of an incorrect medication (Cohen & LaRue, 2005). In this case study the nurse performing a blood transfusion took a bag of saline from the shelf where saline was stored and hung it for completion of the transfusion. Her shift finished, another nurse then administered the pre-hung bag. Unfortunately the bag that the nurse assumed to be saline was actually a misplaced bag of lidocaine (commonly known as lignocaine in New Zealand). The patient died because lidocaine is a local anaesthetic that is cardiotoxic when administered in large doses through the bloodstream. This case study highlights a key issue with medication labels and packaging. The bag of saline and the bag of lidocaine were incredibly similar in appearance. Both were clear liquids in clear plastic wrap, in intravenous (IV) bags that were the same size, had the same colour labels, and neither bag had labelling on the back. The only discernible difference between the labels was a red rectangle containing the words “Lidocaine 2g HCL” (Cohen & LaRue, 2005, pg. 851). Unfortunately a bag of lidocaine ended up where the saline bags were normally located, leading to incorrect selection.

This introduction will outline four factors surrounding medication errors. Firstly, this introduction will examine the rates at which medication errors occur and the influence of labelling and packaging on medication error. Secondly, this introduction will outline previous studies that have attempted to mitigate medication identification errors. Thirdly, this introduction will outline two attentional and behavioural mechanisms that could lead to a medication identification failure: signal detection theory and divided attention. Finally, this introduction will summarise the rationale and method of the current study.

### **The Rates of Medication Error**

In an international review of 91 studies that reported on medication administration errors, Keers, William, Cook, and Ashcroft (2013) determined that medication errors in situations where only one error could be made occurred at a median of 19.6% of the total opportunities for error. When more than one error could be made errors occurred at a median rate of 25.6% of the total opportunities for error. The highest rate of error occurred when the route of administration was intravenous. Across all studies the three most common types of error were wrong dose, omission of the medication and incorrect time of administration.

Of specific interest to this thesis is the rate of medication error in anaesthesiology. A recent review of five studies that reported medication error in anaesthesia conducted by



Cooper and Nossaman (2013) found that errors transpired on average in one out of every 211 anaesthetic medications. On average an anaesthetist will administer around 1000 anaesthetics a year (Webster, Merry, Larson, & Weller, 2001). Therefore, given the error rate it is expected that an anaesthetist will make between four and five medication errors a year.

### **The Contribution of Labelling and Packaging to Medication Error**

A similar case study to the one above was reported by Murdoch, Lane and Goldstein (2004), however in this instance it was a near miss instead of an incorrect administration. During a caesarean section the doctor was about to administer a medication and realised it was a higher concentration than the one usually stocked. The bottle and label were identical to that of the lower concentration, with the exception of the milligram (mg) amount (100mg compared to 50mg). For a similar case study involving ambiguous labelling see Guchelaar, Kalmeijer and Janesen (2004).

Many case studies have identified labelling as a factor contributing to error (Guchelaar, Kalmeijer & Janesen, 2004; Murdoch et al., 2005; Cohen & LaRue, 2005). A review of medical errors reported across America found that as many as one third of medication errors are due to issues with medication labels and packaging (Berman, 2004). Berman stated that label factors such as company logos, manufacturer colours, poor design, and medication specific information (such as dosage or route of administration) can all lead to medication error.

In a review of errors specific to anaesthesia Cooper and Nossaman (2013) reported that labelling was one of the six leading causes of medication error. For example, in a New Zealand study by Webster et al. (2001) medication labelling contributed to 11% of reported errors. Similarly, an American study listed labelling as the cause for 12.5% of reported errors (Cooper, Digiovanni, Schultz, Taylor, & Nossaman, 2012). In contrast, a separate Australian study by Abeysekera, Bergman, Kluger, and Short (2005) reported 32% of errors were due to labelling and packaging. Although there may be variation in the extent to which labelling contributes to medication error it is clear that labelling and packaging contribute to medication error, and solutions need to be examined to ensure safe patient care.

### **Mitigating Medication Error Due to Labelling**

In an attempt to mitigate medical error, several solutions have employed technological aids to avoid human error. One computerised approach is to use a barcode scanning system. These systems vary but the most common use is as a final check of the medication before

administration to the patient or before patients collect prescribed medication. This method of reducing medical error shows promise. A study of pharmacists found that errors were reduced when barcode scanning was implemented in the final stage of dispensing (Riaz, Hashmi, Bukhari, Riaz, & Hussain 2014). Barcode scanning was a more efficient process than a manual check by a pharmacist. However, Cohen and Smetzer (2011) found that barcode scanning may lead to errors when not used optimally and Le Garlantezec et al. (2010) found that barcode scanning did not reduce route of administration errors.

Alternative methods have investigated features of labels that lead to medication error. One commonly cited issue for discriminating one label from another is in the area of name similarity (Lambert, Lin, Chang, & Ghandi, 1999; Lambert, Chang, & Lin, 2001; Lambert, Chang, & Gupta, 2003; Gabriele, 2006). The most commonly used methodology within this area is to present participants with a list of medication names. Participants are later asked to identify whether or not a name from a test list was presented on the previously studied list of medications. It is clear from the literature that similar looking and sounding medication names lead to an increase in false recognition of a medication.

In an attempt to mitigate label confusion due to name similarity Filik, Purdy, Gale and Gerrett (2004) investigated the use of capital lettering (referred to as “Tall Man”) on the recognition of medication names. Tall Man lettering involves capitalising part or half of the word to distinguish it from the rest of the word, e.g. ofloxACIN. Often the part of the word that is capitalised is the part that is different to a similar sounding or looking medication name. Whilst having their eyes tracked medically naive participants viewed a series of arrays that contained medication names and were asked to determine whether a target was present or absent (it was always present). The arrays contained distractor images that were presented in normal text or Tall Man text. Eye data, through the use of eye tracking software, provides useful additional information such as how long and how often an individual looks at information presented on a screen (Rascke, Blascheck, & Burch, 2014). The array was made up of a series of simple medication labels that were presented with the medication name either in all lower case or with half the name capitalised. Filik and Purdy et al. found that the use of capitals in a medication name reduced identification errors and time spent looking at the distractor images in comparison to lowercase distractors.

In a later study, Filik and Price et al. (2010) included trials in which the target was absent, therefore participants could make an additional type of error – reporting that the target was present when it was not. This study found that medical participants (mostly pharmacists) made fewer errors in both the target present and absent trials where Tall Man lettering was

used. Filik and Price et al. pointed out that it would have been useful to include eye-tracking in order to determine whether or not participants were fixating on the portion of the name that contained Tall Man lettering. These findings lead to the conclusion that the use of Tall Man lettering in a medical setting could reduce error rates.

Other researchers found inconsistent effects of Tall Man lettering on medication error. Using medically naive and pharmacy based participants, Schell (2009) found that the presence of Tall Man lettering *increased* the rate of error in target absent trials. However, this research has been criticised by Filik and Price for having a low rate of errors to the point that accuracy was almost at ceiling. The high rate of accuracy could mean that there was no room for evidence of improvement with the presence of Tall Man lettering. Furthermore, in a study assessing the effect of Tall Man lettering in medical professionals Irwin, Mearns, Watson and Urquhart (2013) found no effect of Tall Man lettering. This study did have the added component of time pressure and proximity of targets that could have masked the effects of Tall Man lettering.

Zhong, Feinstein, Patel, Dai, and Feudtner (2012) investigated whether the possible advantages of Tall Man lettering translated to a reduction of error in 42 different children's hospitals in America. Analysis of incident reports revealed that Tall Man lettering did not reduce the likelihood of errors for look-alike and sound-alike medication names. The findings of this study demonstrate that while Tall Man lettering might seem like a promising solution errors still occurred, which indicates that there are other contributing factors that lead to error and these were not reduced by this intervention.

Another strategy towards mitigating medication error involved the use of colour-coding labels. In a New Zealand study, Cheeseman et al. (2011) compared the use of colour coded medications and black and white labels to pre-existing ampoules. Medications were colour coded according to New Zealand and Australian standards. In a simulated target identification task participants selected a medication out of four that matched the name of a target medication presented in the centre of the screen. Participants then confirmed whether or not they wished to administer the selected medication. Results of the study revealed that colour-coded labels were identified faster than either the ampoule or black and white labels. Whilst this method shows promise, research into colour-coding medication has advised caution due to the issues such as errors in medication of a similar type, and inconsistencies in whether or not this method is effective at reducing medication error (Fasting & Gisvold, 2000). Furthermore, factors such as pre-existing associations with colour, the limited range of colours available, and differences in colour-coding schemes both across and within hospitals

have been cited as some of the risks associated with colour-coding medication labels (Shrivastava, Shirvastava, & Ramasamy, 2014).

To summarise, many studies have aimed to reduce the rate of medication error due to labelling by targeting specific label features. The available research indicates that while interventions such as Tall Man lettering or colour-coding medication show some success medication errors still occur. Therefore, it is also important to address other label properties. To date there is limited research that examines the label as a whole.

Bojko, Gaddy, Lew, and Quinn (2005) examined redesigned labels compared to pre-existing labels. The redesigned labels focussed on making label aspects similar and more consistent across medications as well as increasing the salience of important label aspects such as dose and name. Salience of label features was increased in ways such as: replacing all uppercase text with mixed text, reducing the less relevant information on the label, and altering the colour, contrast, and size of label elements. A combination of pharmacists and pharmacy technicians selected target elements of the medications (e.g. the dose) upon presentation of the label and reaction times were recorded along with eye data. It was found that the redesigned labels resulted in faster response times to the label elements compared to pre-existing labels. Eye data revealed that this increase in reaction time was related to a decrease in the number of fixations on an image before a response was made. The authors concluded that the redesigned label template showed promise and that eye tracking software allowed for a more specific analysis of the influence of medication labels and packaging.

A key issue with the work of Bojko et al. (2005) was that their study did not allow for a review of errors made when selecting between medications. Whilst their research demonstrated that the new templates resulted in quicker reaction times in identifying the specific aspects of a label, the participants were never presented with a scenario where they had to discern one medication from another. Therefore, while this research shows promise it does not tap into a key issue surrounding medication error.

A study by Dieckmann, Clemmensen, Sorensen, Kunstek and Hellebek (2014) overcame this limitation by investigating the efficacy of a new labelling system in a sample of medical professionals. Labelling was implemented from a guide for labelling and packaging from the National Patient Safety Agency (National Patient Safety Agency, 2008). Twenty medical professionals completed two medical tasks where they selected and administered medications. They also completed a series of tasks that involved handling and identifying the medications. During the task the medication that was required was always present as well as distractor medications of different doses. Some of the medications included

were from pre-existing labelling and others were from the new label type. Following completion of the tasks participants were interviewed on their perception of the new labelling. From the interviews it was determined that the new label system was clear, easy to read, and many participants noticed the warning signs. The most notable benefits of the new labelling system were in the font and standardisation of the labels. There were, however, some inconsistencies in whether or not different participants perceived the new labels as useful. For example, seven participants reported that the colours were useful in identifying the medication but some reported that the colours used were counter-intuitive to patterns they had already learned in pre-existing labels.

A shortcoming of Dieckmann et al. (2014) was that many participants reported that they did not have sufficient time to learn the new label system and were therefore at a disadvantage when reporting on features that facilitated or inhibited identification. A further critique of the study was that there was no indication of the types of errors made during the simulation task. Therefore, it is difficult to determine from the study whether or not the labels increased performance and accuracy in medical tasks. Furthermore, eye tracking was not used in this task and therefore it is difficult to determine what features participants were attending to throughout the experiment.

Estock et al. (2015) also investigated the efficacy of a new labelling system in a sample of trainee anaesthetists. The same labelling guide from Dieckmann et al. (2014) was utilised in this study. Anaesthesia trainees were asked to administer a medication during a simulation of a high stress operation. The room was stocked with three bags of the required medication (the target medications) and one bag of a medication that was not the required medication (a distractor medication). Both the new and old labels were similar in presentation, however the new labels were presented on an opaque label on both sides of the bag with clear easy to read text and only the key information was present. The old label was printed onto the clear bag, with small text and a large amount of information. Estock et al. found that the redesigned labels led to a significant increase in identification. It is important to note the medications themselves were IV bags which are generally larger in size than injectable medication required during surgery. It is possible that the effectiveness of the new label design may not translate to smaller medications.

In conclusion, the majority of studies that have investigated the role of labelling on medication error have reviewed the efficacy of an intervention designed to mitigate medication error. This thesis differs from the existing literature in that it examined the influence of pre-existing labels on medication error, without testing a new strategy. The

contribution of pre-existing label features to medication error is important to examine as it can add to the existing literature and allow for an integrated assessment of how labelling contributes to medication error.

Three key aspects from the methodology of the previous literature were utilised in this thesis: eye-tracking, target identification, target present and target absent trials. From the above research it is evident that eye tracking is a useful tool in assessing where people look when viewing medications (Bojko et al., 2004; Filik and Purdy et al., 2004; Filik and Price et al., 2010). Studies that include the identification of a target from a selection of stimuli are also useful in determining what factors lead or contribute to error (Filik and Purdy, 2004; Filik and Price et al., 2010; Cheeseman et al., 2011). Finally, studies that allow for a comparison of errors in target absent and target present trials provide an assessment rate of correct and incorrect target judgements and how the presence or absence of the target can alter these rates (Filik and Price et al., 2010).

### **The use of Signal Detection Theory to Investigate Error**

An important aspect of medication identification to consider is the different types of error that can occur. During the process of medication identification a medical professional could do one of four things: they could correctly identify the medication, they could fail to identify the correct medication, they could correctly determine that the medication they are looking for was not present, and finally they could incorrectly select the wrong medication. Signal detection theory provides a mathematical approach to determining levels of accuracy and error across situations where an individual must determine whether a stimulus (the signal) is present or absent (Macmillan & Creelman, 1991). In a setting where a medical professional must determine whether or not a medication is present there are two key factors that can play into that choice: discriminability and bias.

Discriminability is a calculation of an individual's ability to correctly determine whether or not the target is in the array (Macmillan & Creelman, 1991). This measure takes into consideration both the number of times an individual correctly responded that the target was present (hit rate) and the amount of times an individual incorrectly responded that the target was present (false alarm). If an individual has a high rate of responding that the target was present they will have both a high hit rate and a high false alarm rate which means they will have a poor ability to determine whether or not the target was there and thus a low discriminability index. This measure of accuracy is more thorough and informative than a measure of overall accuracy, such as percent correct which does not take into consideration a

participant's overall rate of responding that a target is present. While a participant may have a high percentage of accuracy this may not reflect the possibility that they would also have a high rate of false alarms and an overall bias towards responding that the target is present.

A further useful component of signal detection theory is the ability to measure a bias in responding and identify the effect of that bias on results. A bias is when there is a tendency to favour one response over another (Macmillan & Creelman, 1991). According to signal detection theory the person making the choice will adopt a criterion for determining if a medication is present (Allan & Siegal, 2002). An issue with the criterion for decision is that depending on where it is set it can lead to changes in the types of errors that are made. There are two main types of errors that can arise: a miss and a false alarm. A miss is an error where the medical professional fails to identify a medication that is present in an array. In the case where a large proportion of responses are misses, then the criterion is set towards responding that the target was absent; a conservative criterion. This error could result in a delay in the administration of the correct medication. A false alarm is when a medical professional incorrectly selects the wrong medication. In the instance where a large proportion of errors were false alarms then the criterion is set towards responding that the target was present; a liberal criterion. This error will result in the patient being administered the wrong medication. Therefore, it is necessary to use signal detection theory to discriminate between the two types of error and determine what rate these errors are occurring within the data.

Whilst no known studies have used signal detection theory to investigate medication error, the use of signal detection theory is not uncommon in the field of medicine. Signal detection theory has been useful in determining the types of errors made in determining the efficacy of analgesics (Chapman, Murphy, & Butler, 1973), when analysing decisions of relocation during labour (Cheyne et al., 2012), and when analysing the placebo effect (Allan & Siegel, 2002).

### **The Role of Divided Attention and Medical Experience in Medication Error**

Distraction is an important factor to consider in medical error. When a medical professional is administering a medication there are a variety of other processes and environmental stimuli that are going on. In an operating theatre an anaesthetist must attend to the patient, the surgery, and the selection and administering of medications, while ignoring possible distraction. A study by Campbell, Arfanis, and Smith (2012) observed anaesthetists during surgery and reported a variety of distractions ranging from within and outside the operating theatre. Over the course of the observation 424 distractions were recorded, such as

inappropriately set alarms, conversations, and bleeps. Distraction was reported to cause inattention to a critical task that could lead to error. Abeysekera et al. (2005) found that distraction was responsible for approximately 24% of the medical errors. Further, this inattention accounted for approximately 47% of the errors reported. In a smaller study of two New Zealand hospitals, distraction and inattention accounted for 16% and 13% percent of errors (Webster et al., 2001).

A study by Kataoka, Sasaki, and Kanda (2011) investigated the role of divided attention on student, inexperienced, and experienced nurses' ability to operate an infusion pump. Baseline performance on the task was compared to a divided attention condition, where participants listened to a news recording while completing the infusion. Participants recalled information from the newscast at a later stage. Student and inexperienced nurses demonstrated impaired performance while the performance of experienced nurses was not disrupted by the divided attention task.

A study by Ghazanfar, Cook, Tang, Tait, and Alijani (2015) compared the performance of novice and experienced surgeons performing a laparoscopic procedure under different divided attention conditions. There were three conditions in this study: a control condition with no divided attention task, a task where participants determined a change in tone in a series of continuous beeps (easy level), and a task where participants determined a change in tone and the presence of gaps in a series of continuous beeps (hard level). Novice surgeons had more errors, longer completion times and more movements in the divided attention conditions compared to the control condition. In contrast, the presence of the divided attention conditions did not influence expert participants' performance on the laparoscopic task; however, they were less accurate on the divided attention tasks in comparison to the novice participants.

Stevenson, Schlesinger, and Wallace (2013) investigated the role of a visual divided attention task and auditory noise on the accuracy and speed of detections in oxygen saturations concentrations. Anaesthesiologists detected changes in pitch that corresponded to a change in oxygen saturation of a patient whilst under conditions of divided attention and noise. The divided attention task had three levels of increasing complexity. In the first level participants fixated on a centrally positioned fixation cross while performing the task. In the second level participants saw a string of white letters with a small number (4%) of red letters and responded on a key whenever they saw a red letter. In the third level participants completed the same task with a greater percentage of red letters (20%). All tasks were completed under two conditions: background noise of an operating theatre or no noise.



Results showed that participants made more errors with increasing difficulty of the divided attention task and errors were greater in conditions that contained background noise.

Taken together, the above results demonstrate that distraction in a medical setting can influence error rates. The group of participants that are most at risk of making an error when under the influence of distraction are likely to be novice or inexperienced medical professionals. It is possible that medical training and experience develops the ability to attenuate distraction and prioritise information.

### **The Current Study**

The current study complements a thesis by Badeaux (2015) which examined medication selection in anaesthesia nurses. Badeaux used eye-tracking equipment to examine where novice and expert nurses looked when making target identification judgements on arrays that contained similar and dissimilar distractors. Similar distractors included a feature of the target such as colour, label similarity, container colour, and size. After presentation of the target (the name of a medication), participants made target identification judgements on arrays of nine items. It was found that both experienced and inexperienced nurses were more accurate on target present, compared to target absent, trials. Furthermore, participants spent longer periods of time attending to the bottom of the medication than the top of the medication. A follow-up questionnaire determined that participants identified features of the medications such as the colour and label as factors that impaired the distinguishability of targets.

The current thesis adds to Badeaux's (2015) methodology in two important ways. Firstly, Badeaux reported that participants were more accurate on target present trials. It is possible that this accuracy could be due to an underlying bias of participants to respond that the target is present. The current thesis employed the use of signal detection theory to provide a bias free measure of accuracy and also to determine any underlying biases that may be present. Secondly, Badeaux reported that participants found labelling and colour impaired their ability to discern medications. To determine the role of labelling on medication error, the current thesis reviewed where participants attended to while viewing pre-existing medication labels and packaging. Furthermore, the current thesis assessed the role of labelling on target identification error.

This thesis aimed to investigate both the types of error and biases which occur when selecting a medication as well the conditions in which errors occur. This thesis investigated and attempted to understand what medical professionals look at when viewing medications,

what information they use to make judgements about medications, and what stress does to these judgements. This information could be used to formulate solutions based on the factors that led directly to these errors.

This thesis investigated the cause of medication errors across three studies. The first study, Study 1A – passive viewing – examined where participants look when viewing an image of a medication. The second study, Study 1B – target identification – examined what properties of medications are used to identify the correct medication. The third study, Study 1C – target identification with divided attention – examined what distraction did to this process and how identification strategies change under increased attentional load. In order to get an accurate as possible representation of the problem at hand participants, had their eyes tracked throughout all experiments. Participants were trained medical professionals in the area of anaesthesia and naive controls. For the purpose of this thesis, medical professionals were defined as anyone who administers or handles medications and works in anaesthesia, e.g. doctors, nurses and technicians. Control participants were defined as anyone who does not work (currently or previously) in a profession that handles or administers medications. In order to maximise time and minimise recruitment issues participants completed all three experiments in one session.

## **Chapter Two: Study 1A – Passive Viewing**

The purpose of study 1A was to investigate where participants look at medication labels and packaging without task requirements. To date no known research has been conducted that investigated where medical professionals look when viewing pre-existing medication labels and packaging. This information could be useful as it may be able to guide solutions to medical error. The secondary goal was to use the information gathered in this study to inform predictions on what the data for experiments 1B and 1C might show.

The first research aim was to examine how participants distributed their fixations across the different parts of the medication label. A fixation was recorded as any period of time spent looking at a single point before the participant moved their eyes to a different location. This aim was investigated using an analysis of the total time fixating and the total number of fixations on four key areas of interest (AOIs): the name, dose, top of the medication, and other information. The second research aim was to see whether there were any clear differences in the viewing patterns of medical professionals compared to naive controls. This research aim was analysed using group comparisons of the total time and number of fixations on the four AOIs. These analyses were separated according to the two different packaging types; ampoules and bottles.

If medical experience increases awareness of certain label properties then this awareness will be reflected in differences between fixation times and number of fixations on the four AOIs. Also, if solutions to medical error can be tested on naive controls then there should be no difference between groups.

### **Method**

#### **Participants**

Sixteen medical professionals were recruited from Wellington Regional Hospital and Hutt Valley Hospital (3 nurses, 2 trainee doctor of anaesthesia, 7 doctor of anaesthesia, 3 doctor of anaesthesia senior medical officer, and 1 technician) and 16 control participants were recruited from the Victoria University community. Control participants ranged from 21 to 61 years of age ( $M = 33.88$ ,  $SD = 10.46$ ) and eight were female. Medical participants ranged from 27 to 63 years of age ( $M = 39.86$ ,  $SD = 10.11$ ). An independent samples t-test showed that there was no significant difference between the age of the control and medical participants,  $t(30) = 1.65$ ,  $p = .110$ ,  $d = .58$ . The experience of medical participants ranged from 4 to 37 years ( $M = 14.27$ ,  $SD = 10.34$ ). Every medical participant reported that they

selected and identified medications for the purpose of administration. Seven medical participants reported that they selected and identified medications for storage. See Appendix A for a table of medical participant information. Sixteen participants (six medical) reported normal vision and 16 participants (10 medical) reported corrected-to-normal vision. All participants had normal colour vision as determined by Ishihara (1972) Pseudo Isochromatic Plate colour vision test, 24 plate edition. Participation was voluntary and participants received one movie voucher per hour for their time. Participants gave informed consent and the research was approved through the Victoria University human ethics committee. Participants completed all three experiments in one session that took approximately 60 minutes of their time. Following completion, medical participants responded to six questions about their medical experience, experience with medication error, and views on medication labelling (see Appendix B for the complete survey).

### **Materials**

All stimuli were presented on a Samsung LCD screen (29 x 51 cm) with a refresh rate of 120Hz. The experiment ran using a Dell Precision T1650 monitor operating on a 64-bit system. The experiment was constructed by the author and stimuli were presented using PsychoPY version 1.80.3 (Pierce, 2007).

Stimuli were 32 images of injectable medications. Medications were selected from current medications at Wellington Regional Hospital and images were taken on a plain grey background with consistent lighting across medications. The medications were positioned so that the centre of the image was in the centre of the screen. Images were set to a size whereby the image could be easily read and sizing allowed for the most surface area to be tracked. As a result images were depicted approximately twice their size. Images were presented in colour and all images were oriented in the same direction as the text on the image. The fixation cross and all stimuli were presented on a plain grey screen. Eye position was tracked using an Eyelink 1000 Plus eye-tracking system (SR Research, Mississauga, Ontario, Canada). The two-dimensional coordinates of participant's dominant eye movements were recorded at 1000 Hz. Head movements were limited using a full length head rest that was located 60cm from the screen.

### **Procedure**

A researcher welcomed participants into the lab and then participants completed a consent form and provided demographic information such as age, handedness, eye-sight, and colour vision. To assess colour vision participants were given 10 plates from the Ishihara (1972) PseudoIsochromatic Plate colour vision test, 24 plate edition. Participants passed the

colour vision test if they correctly reported the image in the centre of each plate. To determine eye dominance participants created a triangle with their hands (by placing one hand over the other and creating a gap between the thumb and pointer finger) and with both eyes open positioned their hands so that the centre of a target was in the triangle. Participants then closed each eye one at a time and the eye that still maintained the initial view of the target was recorded as the dominant eye. This method is commonly used to determine eye dominance (Lopes-Ferreira et al., 2013). Once demographic information was collected, participants were seated at the computer, and eye calibration was completed using a 9-point calibration sequence. After a completed calibration and validation sequence participants started the experiment.

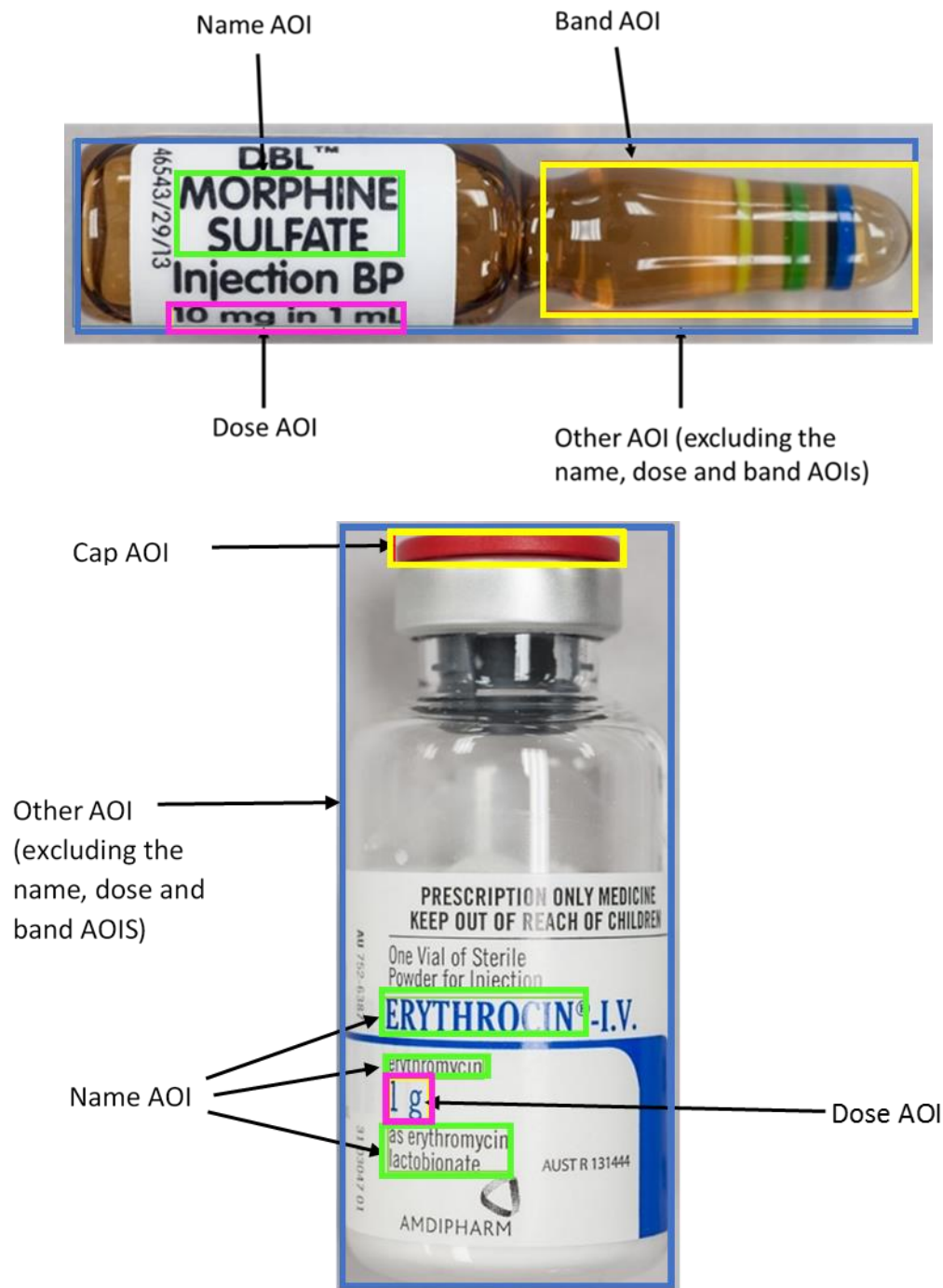
In each trial a fixation cross appeared on the screen for two seconds and participants fixated on the cross until the presentation of the image. The fixation cross appeared in one of four positions: the top centre of the screen, the bottom centre of the screen, the left centre of the screen or the right centre of the screen. The location of the fixation cross was varied across trials. The purpose of the variation was so that at no time did the location of the fixation cross overlap with the presentation of the image. The image was presented on the screen for five seconds, following which a new trial began. Participants were instructed to look at each image. No further instructions were given.

Throughout the experiment three catch trials were presented to participants. These trials were designed to make sure that participants were attending to the images. They contained questions such as “did the previous image contain the colour green?” Participants made judgements on whether or not they agreed with the question on the screen. Participants responded with the ‘1’ key if they thought the answer was yes and the ‘3’ if they thought the answer was no. If participants answered correctly on two out of three of the question then they were counted as attending to the task. All participants correctly answered at least two of the three questions and were counted as attending to the task. Upon completion of the experiment participants were given a self-timed break before moving on with the session.

### **Data Analysis**

The raw eye data from each participant were processed to remove all events that weren't fixations. The fixations were then grouped to total both the number of fixations and the total fixation time within four different area of interest (AOI) categories: Name, Dose, Cap/Band and Other. The Name AOI included any aspect of the labelling that contained the generic and/or ethical name. The Dose AOI included any aspect that contained information about the dose of the medication, such as volume, concentration or total dose. The Cap/Band

AOIs included the part of the label that contained the top portion of the medication; such as the cap on the small bottles and the neck of the ampoule that included the manufacturer's identification bands. The Other AOI included any information that fell within the medication image that was not one of the three previous categories, such as the logo and route of administration. See Figure 2.1 for an example of two stimuli with the AOIs categorised.



*Figure 2.1.* Examples of two different images used in in Study 1A with the AOIs labelled. The top image is an example of an ampoule and the bottom image is an example of a bottle.

Due to the exploratory nature of Study 1A the data were first broken down by image in order to determine whether there were any features that systematically related to differences in either the durations or number of fixations across the four AOIs. The first step in this process was to graph the amount of time fixating and the number of fixations in each of the four AOI categories by each image.

To assess how participants distributed their fixations across the Name, Dose, Cap/Band and Other AOIs of the bottle and ampoule labels the data were also broken down by participant. From the breakdown of data by image and participants it was also possible to determine whether there were any clear differences in the pattern of distribution across the four AOIs between the bottle and ampoules. Finally, it was also possible to assess whether there were any clear differences between how the two groups of participants viewed the medication labels and packaging.

Due to the skew in the distributions of fixations across the four AOIs it was determined that the median was the better representation of the data. Therefore, non-parametric statistics were used to assess the differences between the total fixation times and number of fixations both within and between the two groups of participants.

Ideally to compare the differences between groups that were normally distributed on the total fixation time and number of fixations within the four AOIs two mixed repeated measures ANOVAs would be conducted, one for fixation time and one for number of fixations. There currently exists no non-parametric equivalent of a mixed repeated measures ANOVA, therefore Friedman Tests were used to compare the difference in the total fixation time and number of fixations within the four AOIs for each group. Mann-Whitney U tests were used to compare differences between groups in the total fixation time and number of fixations within the four AOIs.

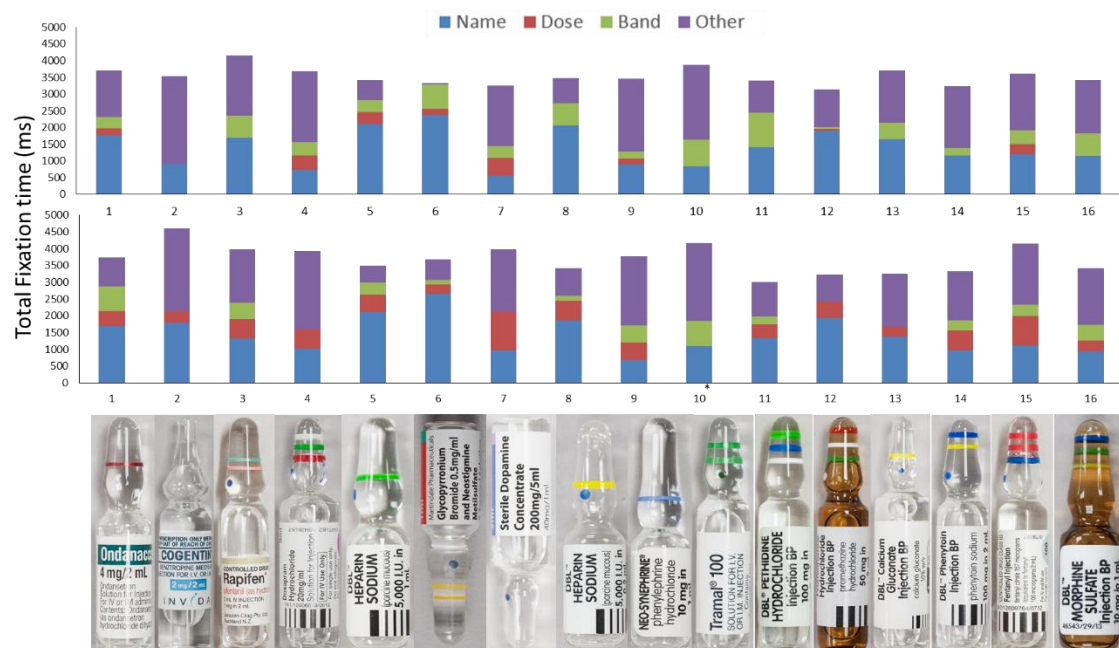
To assess whether participants changed their viewing of AOIs over the course of the study a series of simple linear regressions were conducted. Since the assumption of normality has been violated for these regressions it is important to interpret the results with caution as they cannot be generalised outside this sample (Field, 2009).

## **Results and Discussion**

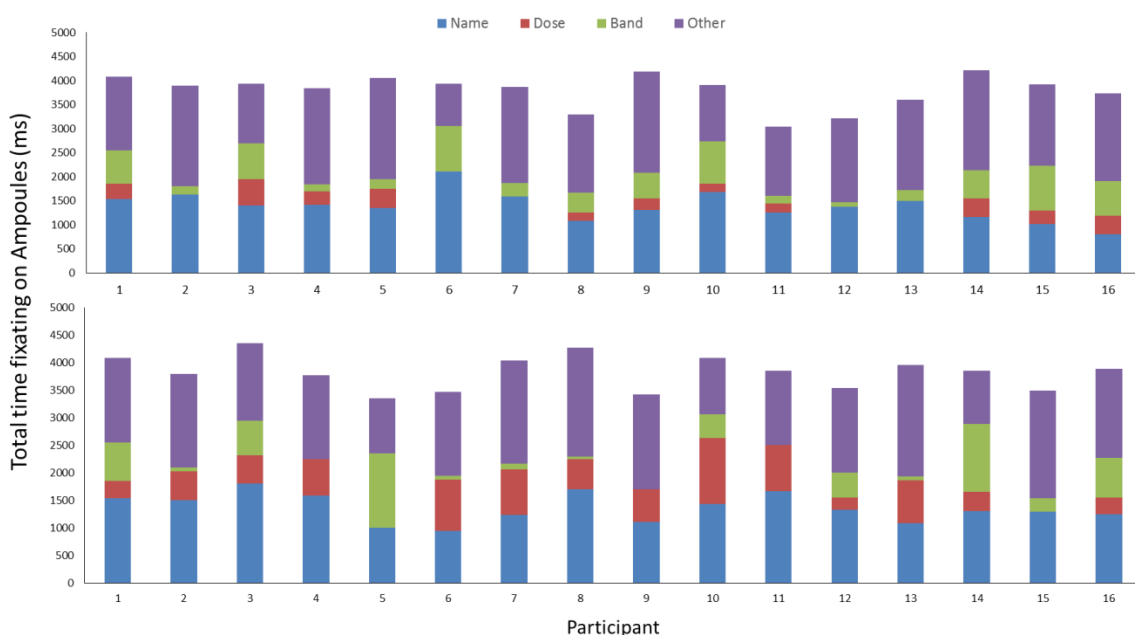
From the survey data 14 of 16 participants reported they had selected an unintended medication. Therefore, medication selection errors were a relevant problem for the current sample. Most participants reported that labelling made it easier for medications to be correctly identified; however, three participants disagreed with this statement.

### Distribution of Total Fixation Time across the Four AOIs

Figure 2.2 presents the total time in milliseconds participants spent fixating on the four different AOIs of ampoule images; Figure 2.3 presents the same data separated by participant. It is clear that both groups of participants fixated on the Name and the Other AOIs for longer than the Band and Dose AOIs; this pattern of fixations can be seen across ampoule images (Figure 2.2) and across participants (Figure 2.3).



*Figure 2.2.* Median total time in milliseconds fixating on each of the four AOI categories (colours in stacked bars) across control (top panel) and medical (bottom panel) participants for each of the 16 ampoule images. All images were presented to participants in the same orientation as the wording. See Appendix C for a larger view of this graph.





*Figure 2.3.* The median total time in milliseconds fixating on ampoule images, by participant, for each of the four AOIs (colours in stacked bar graphs) for control (top panel) and medical (bottom panel) participants.

A Friedman Test revealed that there was a significant difference between the total fixation time in milliseconds on the four different AOIs for ampoules in the control participants  $\chi^2(3) = 39.23, p < .001$ . Post hoc analyses with Wilcoxon Signed-Rank Tests were conducted with a Bonferroni correction applied, resulting in  $\alpha$  level of  $p < .008$ . There was no significant difference between time spent fixating on the Name ( $Mdn = 1387.25ms$ ) and Other ( $Mdn = 1784.25ms$ ) AOIs,  $Z = 2.12, p = .034$ . The median fixation time for all other pairs of AOIs differed significantly, however. Specifically, control participants spent significantly longer fixating on the Name AOI than either the Dose ( $Mdn = 211.50ms$ ),  $Z = 3.52, p < .001, r = 0.62$ , or the Band ( $Mdn = 472.75$ ),  $Z = 3.52, p < .001, r = 0.62$ , AOIs. Control participants spent significantly longer fixating on the Band AOI than on the Dose AOI,  $Z = 2.10, p = .003$ . Finally, control participants spent significantly longer fixating on the Other AOI than either the Dose,  $Z = 3.52, p < .001, r = 0.62$ , or Band,  $Z = 3.46, p = .001, r = 0.61$ , AOIs.

A Friedman Test revealed that there was a significant difference between the total fixation time in milliseconds on the four AOIs for ampoules in the medical participants  $\chi^2(3) = 29.48, p < .001$ . Post hoc analysis with Wilcoxon Signed-Rank tests were conducted with a Bonferroni correction applied, resulting in  $\alpha$  of  $p < .008$ . There were no significant differences between time spent fixating on the Name ( $Mdn = 1313.25ms$ ) and Other ( $Mdn = 1533.50ms$ ) AOIs,  $Z = 1.40, p = .163$ , or the Band ( $Mdn = 176.00ms$ ) and Dose ( $Mdn = 532.00ms$ ) AOIs,  $Z = 1.14, p = .255$ . Consistent with the observations made from Figure 2.3 the median fixation time differed significantly for all other pairs of AOIs, specifically, medical participants spent significantly longer fixating on the Name than either the Dose,  $Z = 3.52, p < .001, r = 0.62$ , or Band,  $Z = 3.41, p = .001, r = 0.60$ , AOIs. Finally, Medical participants spent significantly longer fixating on the Other AOI than either the Dose,  $Z = 3.46, p = .001, r = 0.61$ , or Band,  $Z = 3.36, p = .001, r = 0.59$ , AOIs.

The only clear difference between groups in Figures 2.2 and 2.3 was the amount of time participants spent fixating on the Dose AOI with medical participants fixating for longer periods of time than control participants. To compare the difference in total fixation time on ampoules across the four AOIs between medical and control participants a series of Mann-Whitney U tests were carried out. Bonferroni corrections were applied, resulting in  $\alpha$  level of

$p < .013$ . Consistent with the pattern observed in the graphs, medical participants spent significantly longer fixating on the Dose AOI than controls,  $U = 51.50$ ,  $p = .004$ ,  $r = 0.51$ . There was no significant difference between medical and control participants on the total time fixating on Name,  $U = 120.50$ ,  $p = .777$ , Band,  $U = 87.50$ ,  $p = .127$ , or Other,  $U = 86.50$ ,  $p = .118$ , AOIs.

From Figures 2.2 and 2.3, images where participants spent little to no time fixating on the Other AOI can be explained by the fact that there was not a lot of information captured within this AOI. For example on images five and six it is clear that the name, dose and band information take up the majority of space on the image. Similarly images with a lot of “other” information attracted longer viewing times within that AOI, as seen in images two and ten. Control participants were more likely to spend time fixating on the dose on images where the dose was in close proximity to the name of the medication, for example images four and seven. However, this trend did not persist across all images. For example on image 11 the dose is in close proximity to the name of the medication but the majority of control participants did not fixate on the dose.

Taken together the above results imply that the only notable influence of medical experience is that medical participants paid attention to the dose of the medication. Control participants only attended to the dose of the medication when it was located close to the name of the medication. This difference is important to acknowledge as any study that wishes to implement a solution on differences in the location, size, or properties of the dose information should not test their solutions on medically naive individuals.

Control participants had longer fixations on the Band AOI than the Dose AOI whereas medical participants showed no significant difference. This difference between the groups could be due to the possibility that control participants perceive the bands on the images to be meaningful. It is expected that most medical professionals will know that the bands on an ampoule are for manufacturing purposes and do not convey information about the medication. Control participants may not be aware that they are meaningless and therefore spend more time fixating at and noticing the difference between the bands of different ampoules.

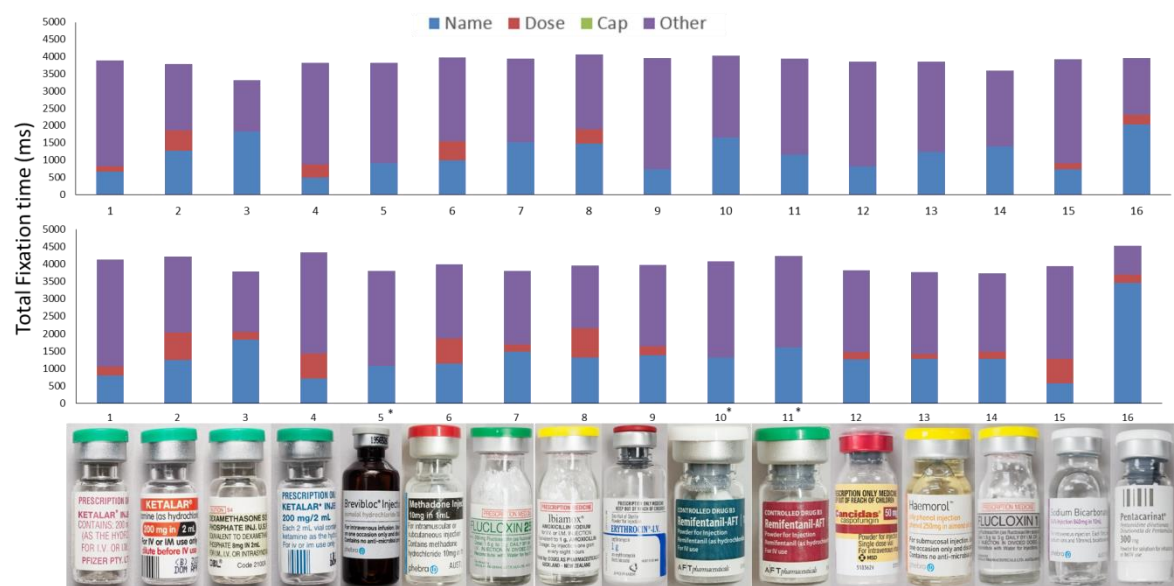
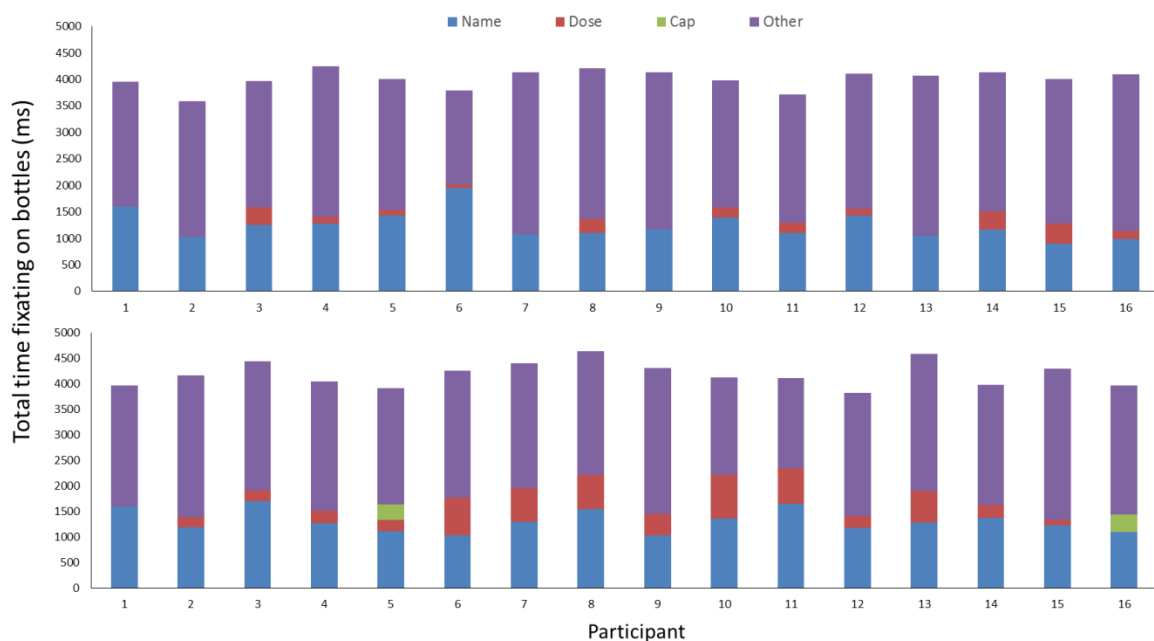


Figure 2.4. Median total fixation time in milliseconds looking at each of the four AOIs (colours in stacked bar graphs) across 16 control participants (top panel) and 16 medical participants (bottom panel) for the 16 bottle images. All images were oriented as shown on the graph. Images with an asterisk represent images where dose information was not present on the image. See Appendix D for a larger version of this graph.

Figure 2.4 presents a comparison of the control and medical participants on the distribution of the total fixation time in the four AOIs across the 16 bottle images; Figure 2.5 presents the same data separated by participants. Similar to the pattern observed in the ampoules where fixations were longer on the Name and Other AOIs compared to the Dose and Cap AOIs.



*Figure 2.5.* The total fixation time in milliseconds, by participant, within each of the four AOIs (colours in stacked bar graphs) for the 16 control (top panel) and 16 medical (bottom panel) participants across all 16 bottle images.

A Friedman Test revealed that there was a significant difference between the total fixation time in milliseconds on the four different AOIs for bottles in the control participants  $\chi^2(3) = 45.77, p < .001$ . Post hoc analysis with Wilcoxon Signed-Rank tests were conducted with a Bonferroni correction applied, resulting in  $\alpha$  level of  $p < .008$ . Consistent with the pattern observed in Figures 2.4 and 2.5, control participants spent significantly longer fixating on the Name AOI ( $Mdn = 1162.50ms$ ) than either the Dose ( $Mdn = 129.75ms$ ),  $Z = 3.52, p < .001, r = 0.62$ , or the Cap ( $Mdn = 0.00$ ),  $Z = 3.52, p < .001, r = 0.62$ , AOIs. Control participants also spent significantly longer fixating on the Dose AOI than on the Cap AOI,  $Z = 2.93, p = .003, r = 0.52$ . Finally control participants spent significantly longer fixating on the Other AOI ( $Mdn = 2589.50ms$ ) compared to either the Name,  $Z = 3.46, p = .001, r = 0.61$ , Dose,  $Z = 3.52, p < .001, r = 0.62$ , or Cap,  $Z = 3.52, p = .001, r = 0.62$ , AOIs.

A Friedman Test revealed that there was a significant difference between the total fixation time in milliseconds on the four different AOIs for bottles in the medical participants  $\chi^2(3) = 45.76, p < .001$ . Post hoc analyses with Wilcoxon Signed-Rank tests were conducted with a Bonferroni correction applied, resulting in  $\alpha$  level of  $p < .008$ . Consistent with the pattern observed in Figure 2.4 and 2.5, medical participants spent significantly longer fixating on the Name AOI ( $Mdn = 1276.00ms$ ) than either the Dose ( $Mdn = 245.00ms$ ),  $Z = 3.52, p < .001, r = 0.62$ , or the Cap ( $Mdn = 0.00ms$ ),  $Z = 3.52, p < .001, r = 0.62$ , AOIs. Medical participants also spent significantly longer fixating on the Dose AOI than on the Cap AOI,  $Z = 2.90, p = .004, r = 0.51$ . Finally, medical participants spent significantly longer fixating on the Other AOI ( $Mdn = 2461.75ms$ ) compared to the Name,  $Z = 3.52, p < .001, r = 0.62$ , Dose,  $Z = 3.52, p < .001, r = 0.62$ , and Cap,  $Z = 3.52, p < .001, r = 0.62$ , AOIs.

From Figures 2.4 and 2.5 it is clear that the only difference between control and medical participants on the time spent fixating on the four AOIs was on the Dose AOI, whereby medical participants fixated for longer periods of time on the dose of the medication than controls. In order to compare the difference in total fixation time on bottles across the four AOIs between medical and control participants a series of Mann-Whitney U tests were carried out. Bonferroni corrections were applied, resulting in  $\alpha$  level of  $p < .013$ . Consistent with the pattern observed in the graphs there was no significant difference between medical and control participants on the total time fixating on Name,  $U = 98.50, p = .266$ , Band,  $U =$

112.00,  $p = .151$ , or Other,  $U = 86.50$ ,  $p = .118$ , AOIs. There was a significant difference between controls and medical participants in the total time fixating on the Dose AOI,  $U = 60.00$ ,  $p = .010$ ,  $r = 0.46$ , whereby medical participants spent significant longer fixating on the dose of the medication than control participants.

Participants spent longer looking at the dose of some bottles than others. Unlike the ampoules, there does not appear to be any systematic reason for the differences between fixation times on dose according to bottle. One clear difference between ampoules and bottles is that in bottles the majority of participants from both groups did not spend time fixating on the cap of the medication producing median total fixation times of zero (absence of green bar sections in Figure 2.4). The only two participants with median fixation lengths on the Cap AOI greater than zero were participants five and 16 from the medical group. Based on the information provided by participants there is not any convincing reason why these two participants displayed a difference in their fixations to the rest of the participants.

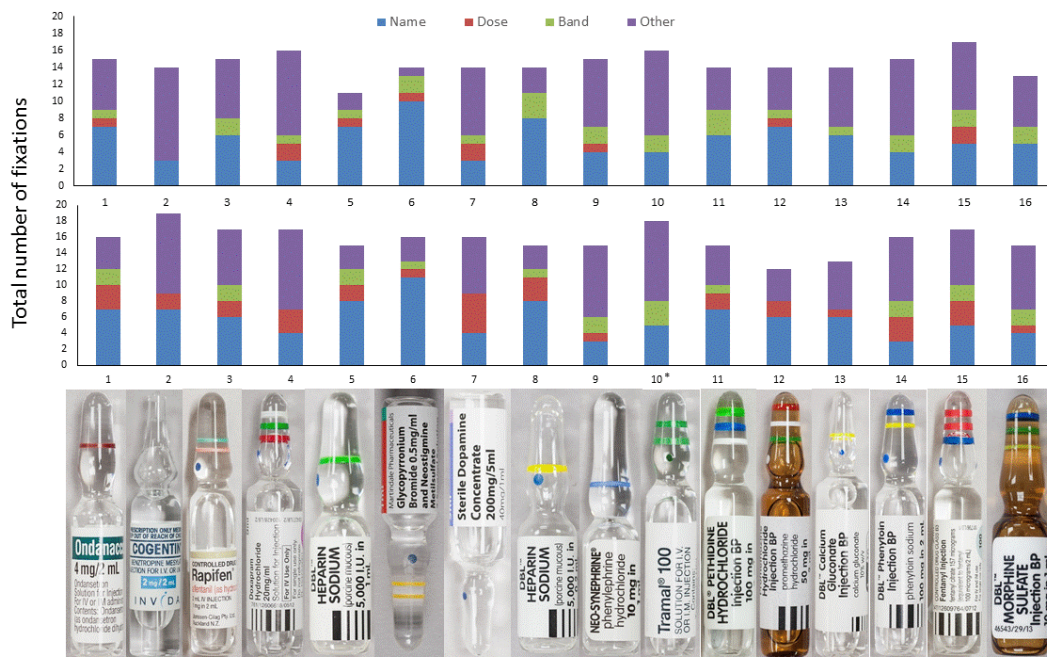
Consistent with the patterns observed in ampoules, both groups fixated on the name of the medication and information not included in the Name, Dose or Cap AOIs than on the dose or cap of the medication. However, control participants looked longer at the dose of the medication than at the cap of the bottle. This pattern is the reverse of the pattern observed in ampoule images and could be accounted for by the fact that the cap of the medication does not appear to signal anything meaningful about the medication. Taken together, these results imply that, similar to the pattern observed in ampoule images, medical experience makes it more likely that individuals will seek out and attend to the dose of a medication.

A further notable difference between packaging types is that for bottle images there was a difference for both groups of participants in the length of fixations within the Name and Other AOIs that was not seen in the ampoule images. For bottle images both groups of participants looked for longer durations at the Other compared to the Name AOI. This difference could be due to the fact that most bottle images had more text included in the other category than ampoule images. This majority of this text included information not captured in the images of the ampoules such as manufacturer logos, information regarding the route of administration, and the phrase “pharmacy only medication”. Consistent with this observation, the fact that participants looked more at the name of the medication than the dose or cap/band of the medication implies that overall participants tended look a AOIs with more text

An alternative explanation of the results is that the Name and Other AOIs were generally larger and included more text than the dose or Cap/Band AOIs. This difference in

size could account for the differences seen in the length of fixations on the Name and Other AOIs compared to the dose and Cap/Band AOIs.

### Distribution of Total Fixation Time across the Four AOIs



*Figure 2.6.* The median total number of fixations in each of the AOIs (colours in stacked bar graphs) across control participants (top panel) and medical participants (bottom panel) for the 16 ampoule images. All images were presented to participants in the same orientation as the wording. See Appendix E for a larger view of this graph

The data were also analysed by the number of fixations made within each AOI. This analysis is important as it provides an assessment of whether or not participants fixated within each AOI more than once across the course of the study. Figure 2.6 presents a comparison between control and medical participants on the median total number of fixations in each of the four AOIs for the 16 ampoule images; Figure 2.7 presents the same data separated by participant. Consistent with the pattern observed in the total fixation times (Figure 2.2 and 2.3), the Name and Other AOIs attracted more fixations than the Dose and Band AOIs. There was no clear difference between the number of fixations within the Name and Other AOIs for either group.

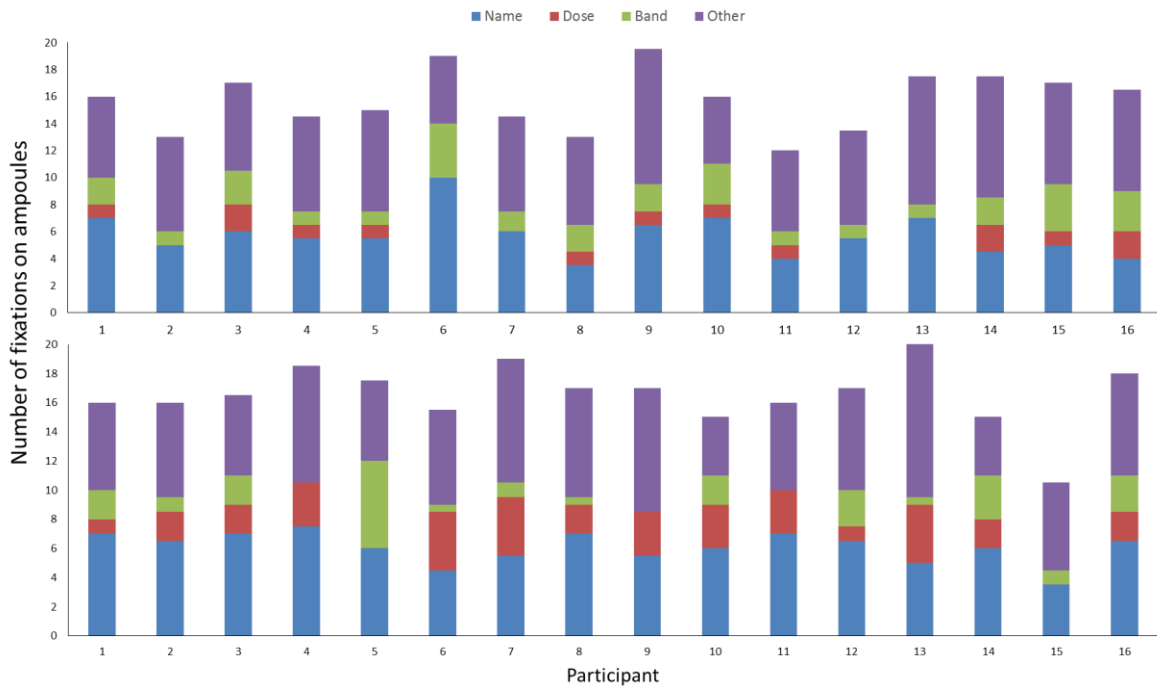


Figure 2.7. Shows the total number of fixations on ampoule images for each of the four AOIs (colours in stacked bar graphs) for control (top panel) and medical (bottom panel) participants.

A Friedman Test revealed that there were significant differences in the total number of fixations in the four AOIs on the ampoule images for control participants  $\chi^2(3) = 44.08, p < .001$ . Post hoc analyses with Wilcoxon Signed-Rank Tests were conducted with a Bonferroni correction applied, resulting in  $\alpha$  level of  $p < .008$ . There were no significant differences between number of fixations on the Name ( $Mdn = 5.50$ ) and Other ( $Mdn = 7.00$ ) AOIs,  $Z = 2.18, p = .029$ . There were significant differences between all other pairs of AOIs, specifically, control participants fixated significantly more often on the Name than either the Dose ( $Mdn = 1.00$ ),  $Z = 3.52, p < .001, r = 0.62$ , or Band ( $Mdn = 2.00$ ) AOIs,  $Z = 3.53, p < .001, r = 0.62$ , AOIs. Control participants fixated significantly more often on the Band than the Dose AOI,  $Z = 3.13, p = .002, r = 0.55$ . Finally, control participants fixated significantly more often on the Other than either the Dose,  $Z = 3.53, p < .001, r = 0.62$ , or the Band,  $Z = 3.52, p < .001, r = 0.62$ , AOIs.

A Friedman Test revealed that there were significant differences in the total number of fixations in the four AOIs on the ampoules for medical participants  $\chi^2(3) = 35.71, p < .001$ . Post hoc analysis with Wilcoxon signed-rank tests were conducted with a Bonferroni correction applied, resulting in  $\alpha$  level of  $p < .008$ . There were no significant differences between time spent fixating of the Name ( $Mdn = 6.25$ ) and Other ( $Mdn = 6.50$ ) AOIs,  $Z = 0.91, p = .361$  or the number of fixations on the Band ( $Mdn = 1.00$ ) and Dose ( $Mdn = 2.00$ )

AOIs,  $Z = 1.40$ ,  $p = .161$ . There were significant differences between all other pairs of AOIs specifically, medical participants fixated significantly more often on the Name than either the Dose AOIs,  $Z = 3.52$ ,  $p < .001$ ,  $r = 0.62$ , or the Band,  $Z = 3.42$ ,  $p < .001$ ,  $r = 0.60$ , AOIs. Finally, medical participants fixated significantly more often on the Other AOI than either the Dose,  $Z = 3.52$ ,  $p < .001$ ,  $r = 0.62$ , or Band,  $Z = 3.47$ ,  $p = .001$ ,  $r = 0.61$ , AOIs.

Figures 2.6 and 2.7 revealed that medical participants fixated more often on the dose of the medication compared to control participants. As indicated by the size of the red in the stacked bar graphs medical participants fixated more frequently of the dose of the medication than controls. Control participants fixated more on the band compared to the dose of the medication. This pattern was not as pronounced in the medical participants. In order to compare the difference in the total number of fixations on ampoules across the four AOIs between medical and control participants a series of Mann-Whitney U tests were carried out. Bonferroni corrections were applied, resulting in  $\alpha$  level  $p < .013$ . Consistent with the pattern observed in the graphs there was no significant difference between medical and control participants on the total number of fixations on Name,  $U = 98.50$ ,  $p = .270$ , Band,  $U = 88.00$ ,  $p = .138$ , or Other,  $U = 105.50$ ,  $p = .393$ , AOIs. There was a significant difference between controls and medical participants in the total number of fixations on the Dose AOI,  $U = 48.50$ ,  $p = .002$ ,  $r = 0.55$ , whereby medical participants fixated more often on the dose of the medication than controls.

In combination with the results from the total fixation time in ampoules, these results show that not only did both groups of participants spend longer fixating on the Name and Other AOIs in comparison to the Dose and Band AOIs they also looked more often at these AOIs. Furthermore, for ampoule images medical participants looked more frequently as well as longer at the dose of the medication than control participants.



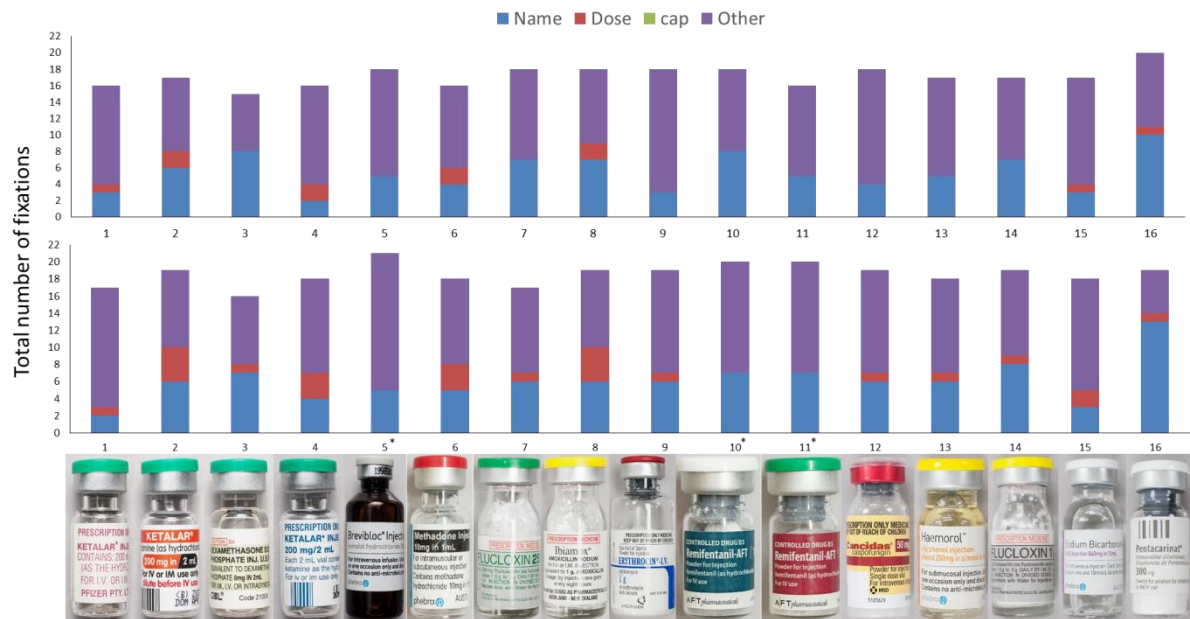


Figure 2.8. The median total number of fixations in each of the four AOIs (colours in stacked bar graphs) across the 16 control (top panel) and 16 medical (bottom panel) participants for the 16 bottle images. See Appendix F for a larger version of this graph.

Figure 2.8 presents a comparison between medical and control participants of the total number of fixations in the four AOIs across the bottle images, Figure 2.9 presents the same data separated by participant. Similar to the pattern observed in the total fixations times (Figure 2.4) it is clear that the Name and Other AOIs attracted more fixations than the Dose and Cap AOIs. Again, it is evident from the absence of green in the bar graphs that the modal behaviour for control and medical participants was to not fixate within the Cap AOI. The only clear difference between groups is that medical participants fixated more often on the dose of the medication.

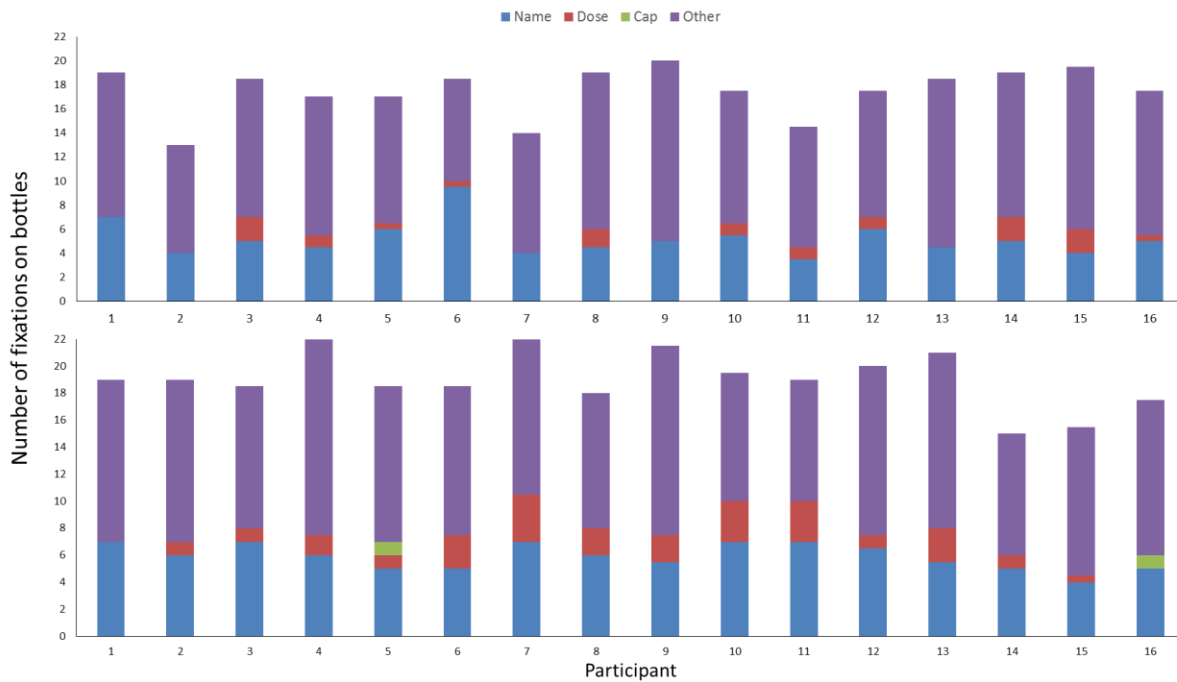


Figure 2.9. The total number of fixations within each of the four AOIs (colours in stacked bar graphs) for the 16 control (top panel) and 16 medical (bottom panel) participants across all 16 bottle images.

There were more fixations on the Other AOI than on the Name, Dose or Cap AOIs. Further, there were more fixations on the name of the medication in comparison to the cap and dose of the medication.

A Friedman Test revealed that there were significant differences in the total number of fixations in the four AOIs on the bottles for control participants  $\chi^2(3) = 45.77, p < .001$ . Post hoc analysis with Wilcoxon Signed-Rank tests were conducted with a Bonferroni correction applied, resulting in a level of  $p < .008$ . Consistent with the pattern observed in the Figure 2.8 and 2.9 control participants fixated significantly more often on the Name AOI ( $Mdn = 5.00$ ) than either the Dose ( $Mdn = 0.75$ ),  $Z = 3.52, p < .001, r = 0.62$ , or Cap ( $Mdn = 0.00$ ),  $Z = 3.53, p < .001, r = 0.62$ , AOIs. Control participants also fixated significantly more often on the Cap than the Dose AOI,  $Z = 2.96, p = .003, r = 0.52$ . Finally, control participants fixated significantly more often on the Other AOI ( $Mdn = 11.00$ ) than the Name,  $Z = 3.47, p = .001, r = 0.61$ , Dose,  $Z = 3.53, p < .001, r = 0.62$ , or Cap,  $Z = 3.52, p < .001, r = 0.62$ , AOIs.

A Friedman Test revealed that there were significant differences in the total number of fixations in the four AOIs on the bottles for medical participants  $\chi^2(3) = 46.48, p < .001$ . Post hoc analysis with Wilcoxon Signed-Rank tests were conducted with a Bonferroni correction applied, resulting in a level of  $p < .008$ . Consistent with the pattern observed in

Figure 2.8 and 2.9 medical participants fixated significantly more often on the Name AOI ( $Mdn = 6.00$ ) than either the Dose ( $Mdn = 1.25$ ),  $Z = 3.53$ ,  $p < .001$ ,  $r = 0.62$ , or the Cap ( $Mdn = 0.00$ ),  $Z = 3.53$ ,  $p < .001$ ,  $r = 0.62$ , AOIs. Medical participants also fixated significantly more often on the Dose AOI than the Cap AOI,  $Z = 3.06$ ,  $p = .003$ ,  $r = 0.54$ . Finally, medical participants fixated significantly more often on the Other AOI ( $Mdn = 11.50$ ) than either the Name,  $Z = 3.52$ ,  $p < .001$ ,  $r = 0.62$ , Dose,  $Z = 3.52$ ,  $p < .001$ ,  $r = 0.62$ , or Cap,  $Z = 3.52$ ,  $p < .001$ ,  $r = 0.62$ , AOIs.

One difference between the participant (Figure 2.9) and image graph (Figure 2.8) is that when viewing the data by participant it is clear that two medical professionals fixated regularly on the cap of the bottle medication whereas no control participants showed this behaviour. This pattern was also observed in the total fixation times. This indicates that while it is important to look at differences between the groups it is also important to take into consideration that there is large amount of individual variability within each group of participants. This individual variability is important to acknowledge because it could be this variability that increases or decreases the rate of error in medical setting. For example the two participants who attend more to cap of the medication may make different errors to an individual who does not attend to the cap of the medication. Future research could examine contributors to this variability such as experience and self-reported medication identification strategies.

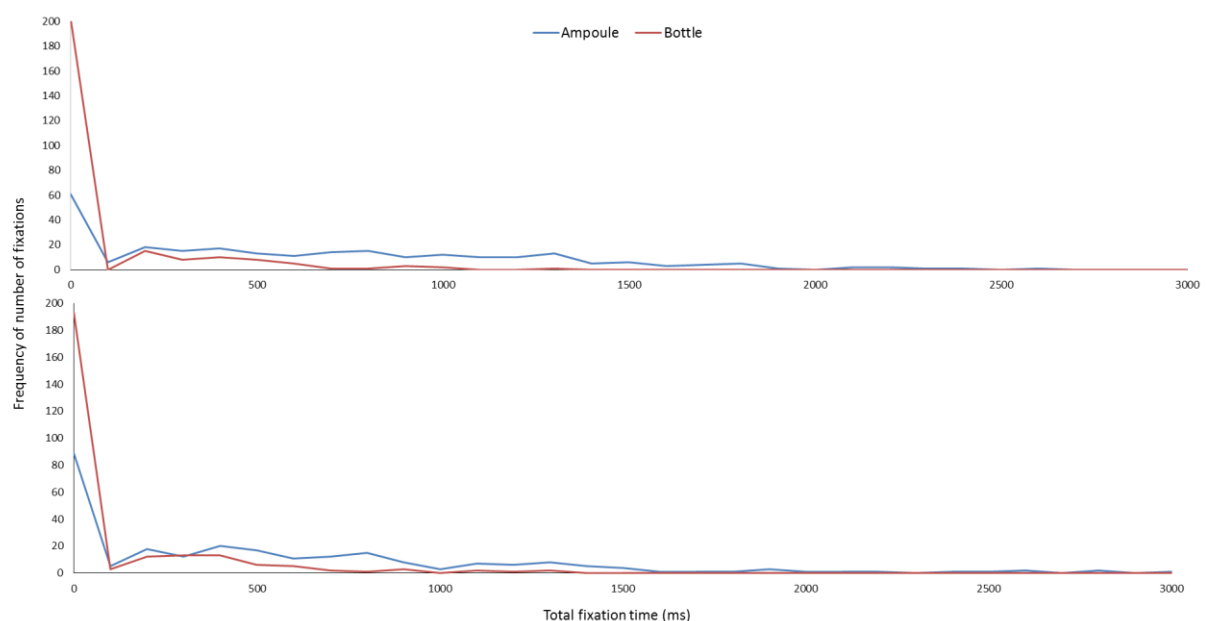
Apart from this minimal difference there were not any clear differences between groups in the distribution of fixations across the four AOIs. Some of the medical participants did look slightly more often at the dose of the medication than typical control participants but this pattern was not consistent. In order to compare the difference in the total number of fixations on bottles across the four AOIs between medical and control participants a series of Mann-Whitney U tests were carried out. Bonferroni corrections were applied, resulting in  $\alpha$  level  $p < .013$ . Consistent with the pattern observed in the graphs there was no significant difference between medical and control participants on the total number of fixations on Name,  $U = 69.00$ ,  $p = .024$ , Band,  $U = 112.00$ ,  $p = .151$ , Other,  $U = 125.00$ ,  $p = .909$ , or Dose,  $U = 73.00$ ,  $p = .035$ , AOIs.

In combination with the findings in the total number of fixations on bottle images these results show that not only do participants fixate longer on the Name and Other AOIs compared to the Dose and Cap AOIs they also fixate more often on these AOIs. The increase of fixations seen in both groups of participants on the Other compared to the Name AOI can

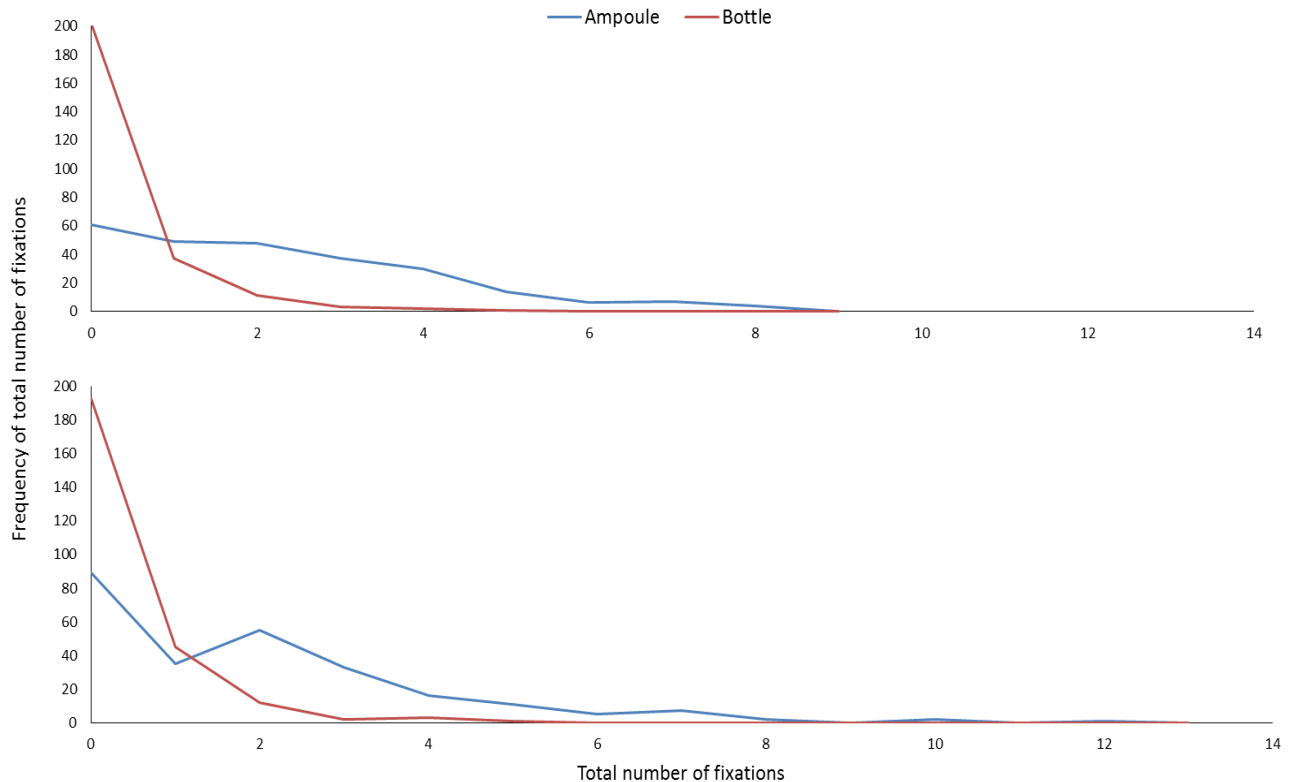
once again be attributed to the fact that there is more text in the Other AOI than the Name AOI and that the other AOI is larger in size than the Name AOI.

The only difference between patterns seen in the number of fixations compared to the total duration of fixation is between the control and medical participants' fixations on the Dose AOI. The total fixation time comparisons showed that medical participants fixated for significantly longer on the dose of the medication in comparison to control. This pattern was not reflected in the number of fixations. This difference implies that while medical professionals may look for longer durations at the dose of the bottle images they do not look at the dose more frequently than controls.

A consideration of these graphs is that they reflect the median time spent fixating on each of the AOIs. Whilst the median provides useful information for what the main behaviour was it is also interesting what the distribution of fixations was across images and participants. Of particular interest was that for both groups of participants the median fixation time and number of fixations for looking at the cap of the bottle images was zero.



*Figure 2.10.* A frequency histogram of total number of fixations (in 500ms bins) on the Cap and Band AOIs for both ampoule (blue line) and bottle (red line) images across all control (top panel) and medical (bottom panel) participant.



*Figure 2.11.* A frequency histogram of total number of fixations on the Cap and Band AOIs for both ampoule (blue line) and bottle (red line) images across all control (top panel) and medical (bottom panel) participants.

Figure 2.10 presents a comparison between control and medical participants of the frequency of the total time spent fixating on the cap of the bottle medications. This frequency distribution was constructed by taking the total number of images viewed by that group (16 participants x 32 images) and calculating the number of trials on which the duration of time spent fixating on the top of the medication fell within each bin. Figure 2.11 presents the same information by the number of fixations. It is clear from Figures 2.10 and 2.11 that the majority of control and medical participants do not look at the cap of the bottle whereas (as indicated by the height of the red line at zero total number and time of fixations) more participants look at the band of the ampoules. The distribution of fixations evident in Figure 2.10 and 2.11 indicates that while the majority of fixations on the cap of the bottle images were at zero some fixations were for longer periods of time and occurred more than once on the cap of the medication.

### **Changes in Viewing over Time**

In order to assess whether or not participants changed the way they viewed the medications across the course of the experiment the images were separated by type (ampoule

or bottle) and then ordered by trial. This allowed an assessment of the stability of patterns of fixations described above over time. This was of particular interest for the control participants as they may not have seen the medication labels used previously. Figure 2.12 presents a comparison between control and medical participants of the trial breakdown for the total fixation time across ampoule images for both control and medical participants.

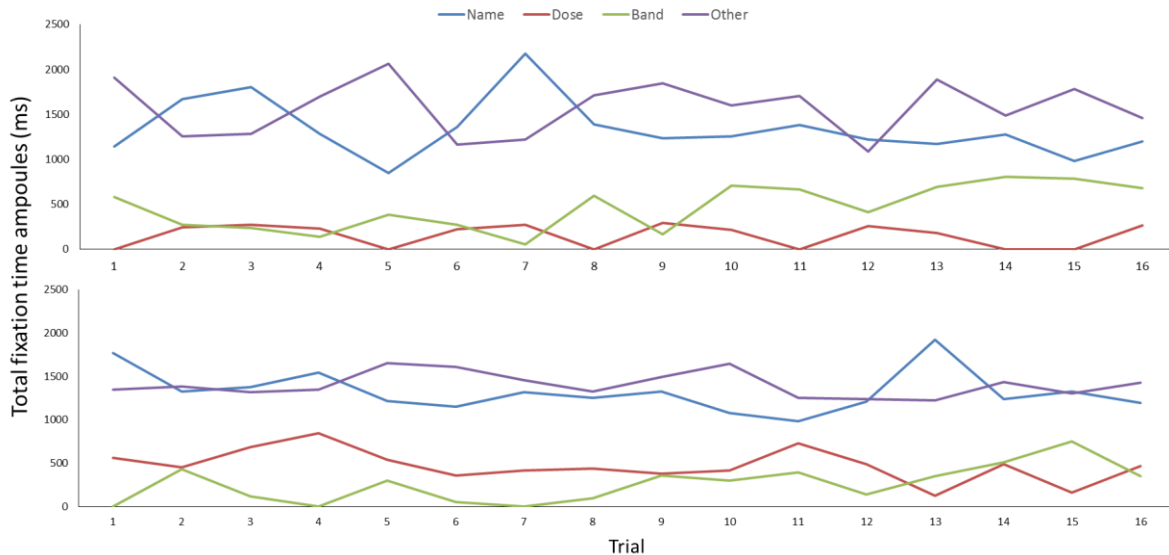


Figure 2.12. The median total fixation time across ampoule images for control (top panel) and medical (bottom panel) participants ordered by trial.

The only clear change in behaviour across trials is on the time spent fixating on the bands of the ampoules. Control participants show slight rise in total fixation time towards the end of the ampoule trials. The same rise in fixation time on the band of ampoules can be observed in medical professionals. Consistent with the pattern observed in the graphs a linear regression between the total fixation times on the band of the medication by the trial of the experiment revealed that trial explained a significant amount of variance in the total fixation time in milliseconds spent looking at band for controls,  $F(1, 14) = 10.03$ ,  $p = .007$ ,  $R^2 = .38$ , and for medical participants,  $F(1, 14) = 8.15$ ,  $p = .013$ ,  $R^2 = .37$ . The analysis shows that trial did significantly predict changes in fixation time on the Band AOI in control,  $\beta = 34.13$ ,  $t(15) = 3.18$ ,  $p = .007$ , and medical participants,  $\beta = 27.41$ ,  $t(15) = 2.85$ ,  $p = .013$ , with longer fixations on the band occurring in the later trials of the experiment. All other fixation times within the Name, Dose and Other AOIs varied unsystematically across trials and all other regressions were non-significant ( $p > .05$ ). To determine whether the rise in fixation time for control participants looking at the bands of ampoules is mimicked by the number of fixations Figure 2.13 was constructed.

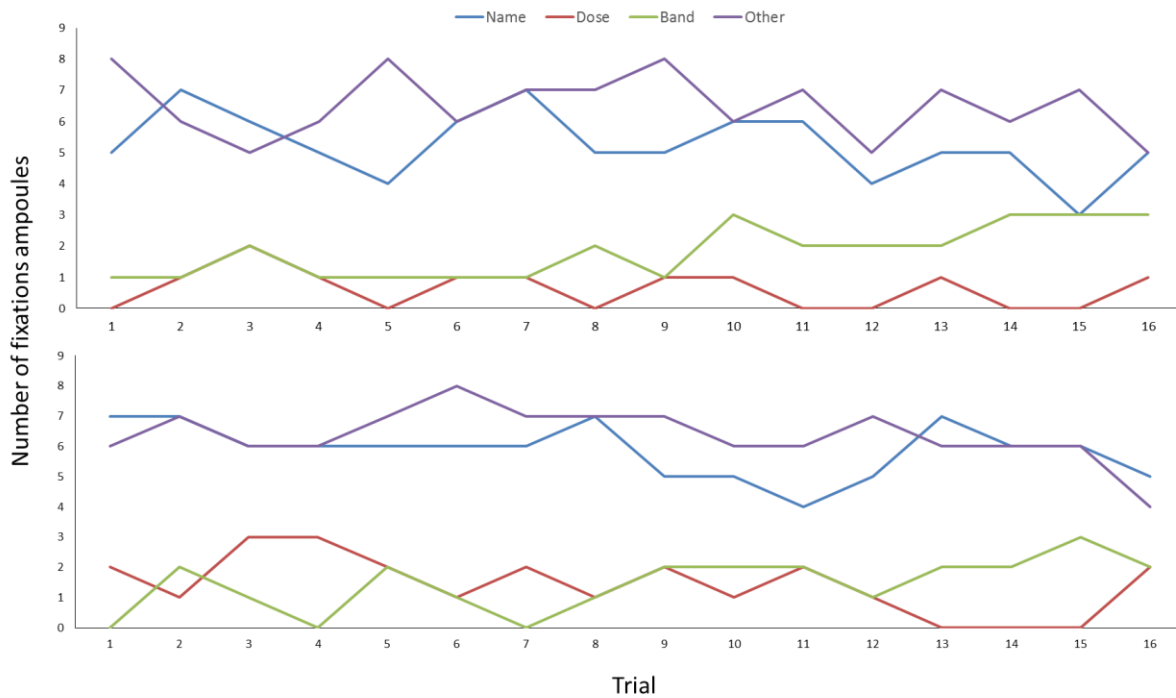


Figure 2.13. The median total number of fixations across ampoule images for control (top panel) and medical (bottom panel) participants ordered by trial.

Figure 2.13 presents a comparison between control and medical participants on the breakdown of the distribution of the number of fixations across the four AOIs over the course of the experiment. Similar to the pattern seen above control and medical participants show a rise in of fixations within the Band AOI. Consistent with the pattern observed in the Figure 2.13 a linear regression between the total number of fixations on the band of the medication by the trial of the experiment revealed that trial explained a significant amount of variance in the total number of fixations on the band for control,  $F(1, 14) = 6.55, p = .023, R^2 = .27$ , and medical participants,  $F(1, 14) = 8.05, p = .013, R^2 = .37$ . The analysis shows that trial did significantly predict changes in the number of fixations for control,  $\beta = 0.27, t(15) = 2.56, p = .023$  and medical participants,  $\beta = 0.11, t(15) = 2.84, p = .013$ , with more fixations on the band of the medication occurring in the later trials of the experiment. The only other pattern is that there was a decrease across the course of the experiment in the total number of fixations on the dose of the ampoule images in medical participants. Consistent with the pattern observed in the graphs a simple regression between the total number of fixations on the dose of the medication by the trial of the experiment revealed that trial explained a significant amount of variance in the total number of fixations on the Dose AOI,  $F(1, 14) = 6.37, p = .024, R^2 = .31$ . The analysis shows that trial did significantly predict changes in the number of fixations on dose ( $\beta = -.11, t(15) = 2.52, p = .024$ ) with fewer fixations on dose of

the medication occurring in the later trials of the experiment. All other regressions were non-significant ( $ps > .05$ ).

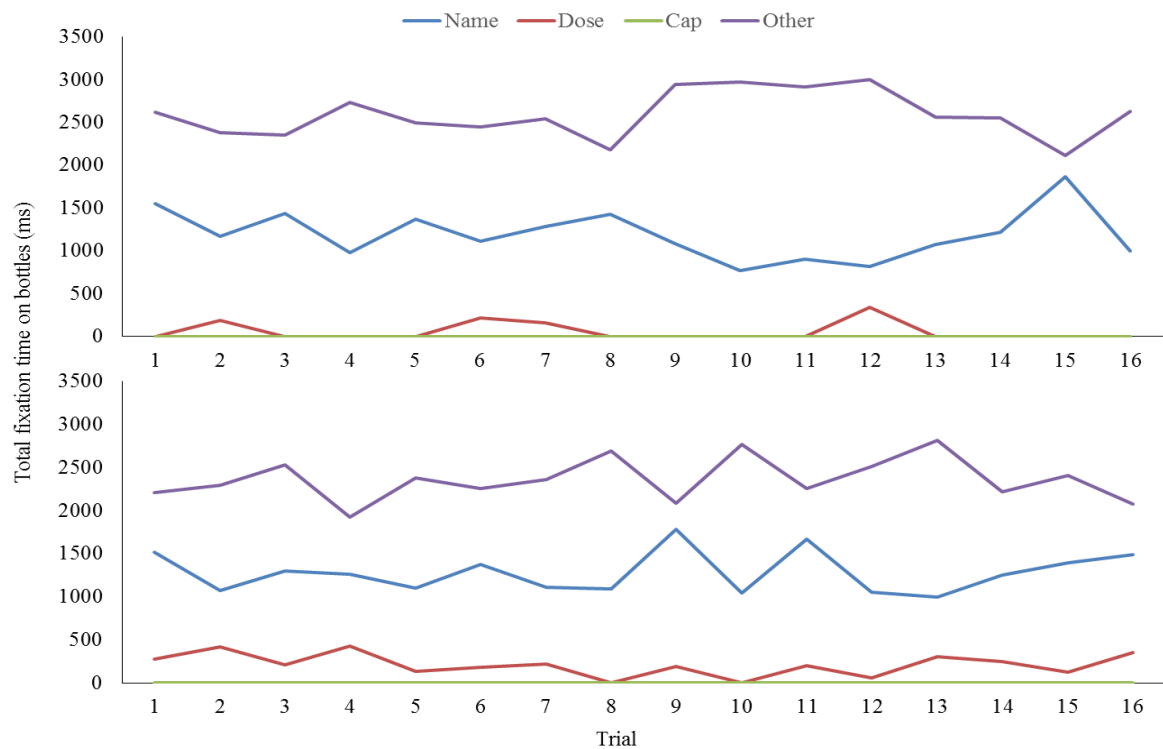
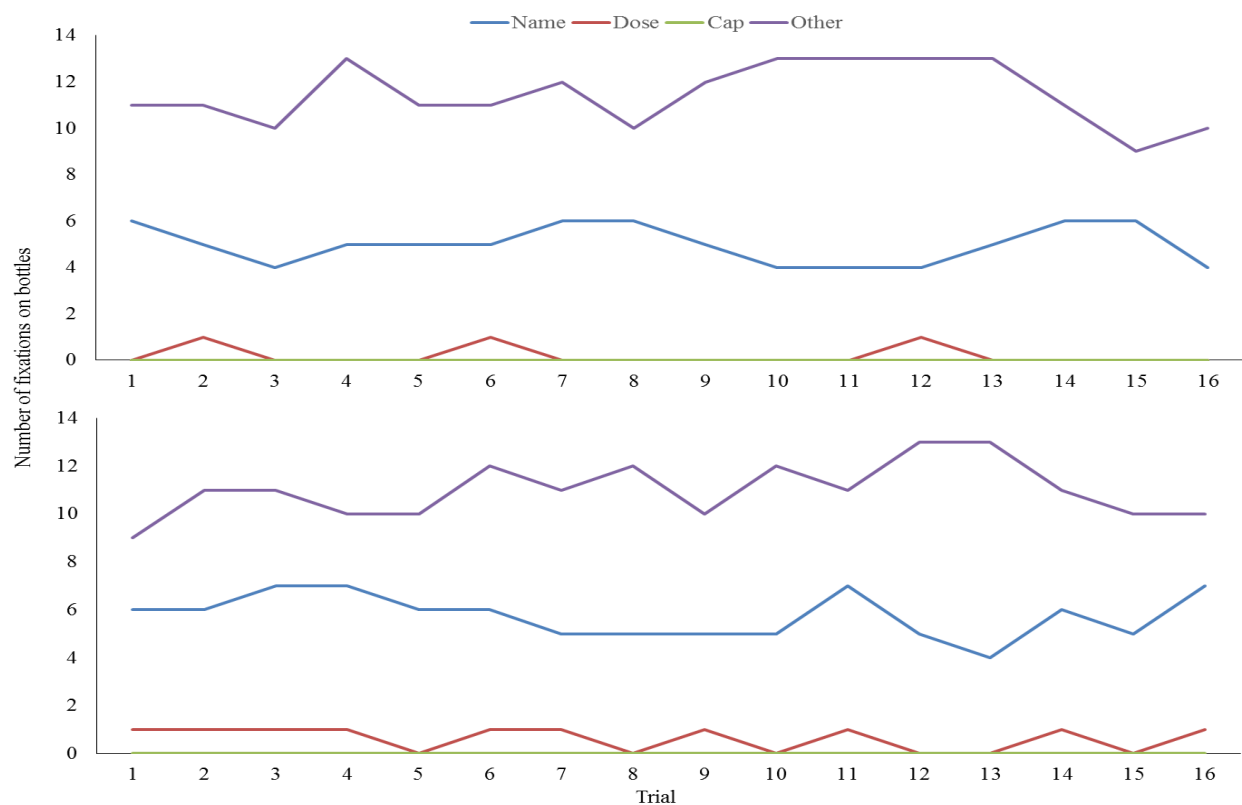


Figure 2.14 a line graph of the median total fixation time in milliseconds on bottle images for control (top panel) and medical (bottom panel) participants ordered by trial.





*Figure 2.15.* Median number of fixations on bottle images for control (top panel) and medical (bottom panel) participants ordered by trial.

Figures 2.14 and 2.15 presents the total fixation time and total number of fixations on bottle images across the 16 trials made by both groups of participants. Unlike the ampoules there are no consistent changes in either the total fixation time or number of fixations within any of the four AOIs across the course of the experiment. These results indicate that neither control nor medical participants changed how they view the bottle images throughout the experiment.

Taken together, these results imply that both control and medical participants attended more frequently and more often to the band of the ampoule images as the session progressed. A possible explanation of this pattern is that while the bands of ampoule images are not meaningful and are only present for manufacturing purposes they could attract the attention of participants in two different way. Control participants may fixate on the bands of the ampoule images because this variation could signal to them that they bands mean something in relation to the medication. Medical participants are likely to know already that the only purpose of the bands in the medication is for the manufacturer and they do not in any way signal anything about the medication. Therefore, the bands could capture the attention of the medical participants because they are something that they do not normally need to, and thus get to, attend to in an operating theatre.

### **Conclusion**

The findings from Study 1A indicated that both groups of participants looked for longer and more often at the Name and Other AOIs than the Dose and Cap/Band AOIs for both the ampoule and bottle medication. There was no consistent difference between the length or number of times participants looked at the Other AOI compared to the Name AOI, while viewing the ampoule images. There was, however, a difference in the bottle images whereby both groups of participants looked more frequently and for longer at the Other compared to the Name AOI.

The only significant difference between groups for the number and length of fixations on the four AOIs was on the Dose AOI for ampoule images whereby medical participants looked longer and more often at dose than controls. This pattern was visible in the total fixation times on bottle images, however the significant difference for the number of fixations on dose disappeared after controlling for multiple comparisons. Together these results indicate that medical training leads to a difference in how participants view the dose

information of medications. There was no other consistent influence of medical training evident in the viewing times and number of fixations for the other three AOIs.

### Chapter Three: Study 1B – Target Identification

A key focus of experiment 1B was to investigate the types of errors that occur during target identification. This question was analysed using a target identification procedure with a signal detection theory analysis of error based on discriminability index and bias. In an operating theatre anaesthetists make judgements on whether or not a required medication is in the drug trolley. If a medication is determined to be present then the selected medication (which may not necessarily be the correct medication) is then administered into the patient.

As mentioned in the introduction there are four possible outcomes in this scenario: a hit whereby the medication professional correctly identified the medication, a correct rejection whereby the medical professional correctly determined that the medication was absent from the trolley, a miss whereby the medication professional incorrectly determined that the medication was absent from the trolley, and, finally, a false alarm whereby the medical professional selected the incorrect medication.

This study utilised a target identification procedure whereby participants were presented with a target medication followed by a screen of four medication images (i.e. an *array* of images) which contained the target on half of the trials. Participants made a response based on their determination of whether or not the target was present or absent. Following that judgement they were then presented with another screen and responded with the location of where they thought the target was in the array. The arrays were designed so that each array contained distractors that varied in similarity to the target medication.

By considering both the hit rate and false alarm rate the discriminability index measure of signal detection theory allows for the determination of an individual's ability to reliably distinguish whether or not a target is present (Macmillan & Creelman, 1991). If medical training increases an individual's ability to determine whether or not a target is present in the trolley then medical professionals should show a higher discriminability index than controls.

The criterion measure of bias determines the position of the selection threshold of an individual (Macmillan & Creelman, 1991). In relation to this study a negative criterion indicates that participants were biased towards responding that the target was present, which would result in an increased number of hits and false alarms, and a positive threshold indicates that participants were biased towards responding that the target was absent, resulting in an increase of correct rejections and misses. A criterion of zero indicates that there is no bias present in the target identification judgements of an individual. If medical

experience increases the ability of a medical participants to correctly determine whether or not a medication is present regardless of any bias then medical professionals should show greater discriminability indices than control participants. Signal detection theory research has found that false alarms occur when the target is likely to be in the array (Swets, 1998). Whilst the target probability of the current experiment was 50% medical professional's come from an environment where the commonly used medications are more likely to be present than they are to be absent. Therefore, if medical experience increases bias because the medication is always present in the trolley then medical professionals should show a more liberal criterion than controls.

In addition to the analysis of error through signal detection theory, the secondary aim of this study was to determine which label features lead to error. This question was answered by systematically reviewing each error and determining how the selected distractor differed from the target. This analysis was possible because the arrays that participants made their selection from contained distractors that differed on an increasing range of features to the target image. Similar to Study 1A the four factors that were assessed were: name, dose, cap/band and other. In relation to identifying a medication four predictions can be made based on the findings from Study 1A. Firstly, since both groups of participants looked at the Name and Other AOIs more than the dose AOI participants may be more likely to make errors on medications that only differ from the target on the dose of the medication. If participants are not attending to the dose of the medication then they may incorrectly select medications that where the only difference to the target was the dose of the medication. Secondly, since both groups of participants fixated for longer periods of time and more often of the Name and Other AOIs it is expected that changes to these AOIS will be more likely to be identified than changes to the dose or band of the medication. Therefore, participants should make fewer errors on distractors that have changes to the "other" features and name. Thirdly, since control participants fixated on the dose of the medication less often and for shorter periods of time than the medical participants then control participants will make more errors on medications where the dose of the images was the only change than will medical professionals.

## **Method**

### **Participants**

Participants were the same 16 medical professionals and 16 controls as those in the passive viewing experiment.

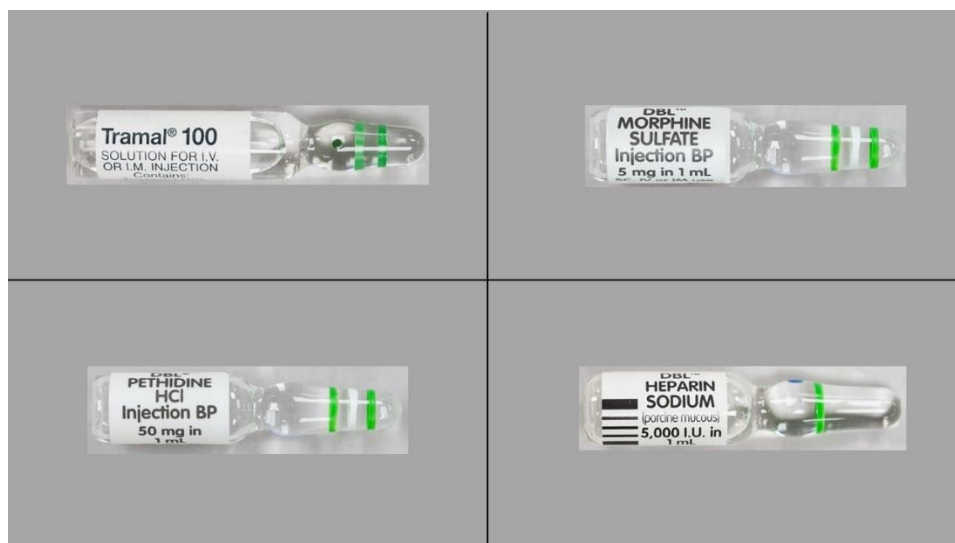
## Materials

Throughout the experiment participants saw 32 target medications and determined whether or not the target medication was present in a following array of four medications. Targets were images of 32 injectable medications taken at Wellington Hospital (see Figure 3.1 for an example of a target image). The same computer specifications that were used in experiment 1A were also used throughout experiment 1B.



*Figure 3.1.* Example of a target ampoule image. Bottle images were also used throughout the experiment.

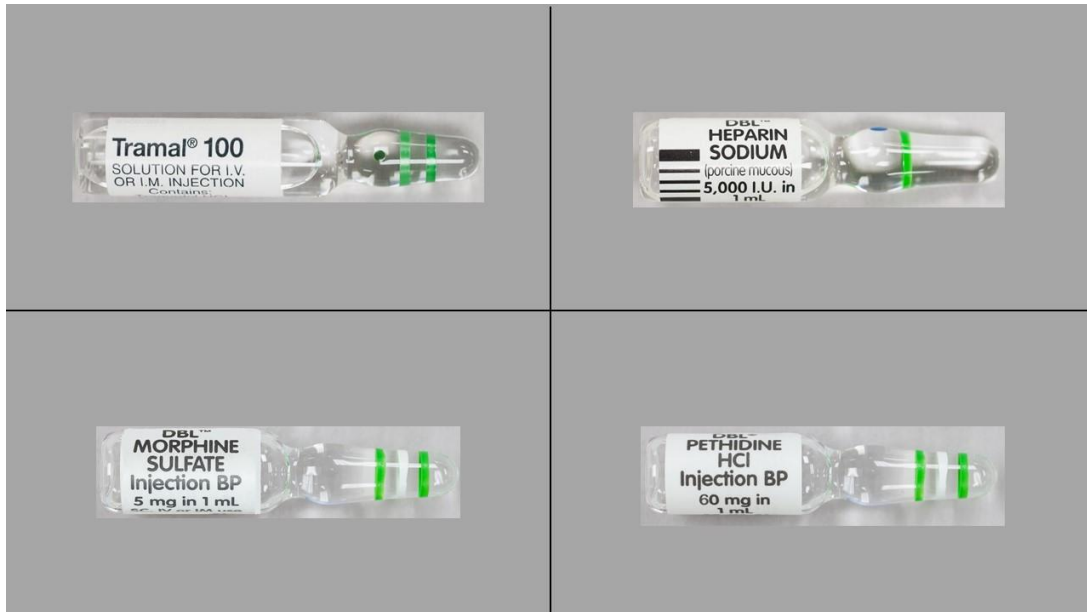
**Arrays.** Each target present array contained the target image and three distractor images. The images were set into the four quadrants of the screen with black lines separating the images. Distractor images varied on a continuum of similarity to the target based on five properties: colour, dosage, label information, shape and name. In an array, the most similar distractor was similar to the target on all but one or two dimensions. For example the most similar distractor might have the same shape, label properties, colour, dosage, and size as the target but a different name. The second most similar distractor would be similar to the target on all but two or three dimensions and the third would be similar on all but three or four dimensions. All images were altered by the author using CorelDRAW graphics suite X7. See figure 3.2 for an example of a target present array for the target example in Figure 3.1.



*Figure 3.2* an example of a target present array. The target is present in the bottom left hand corner of the array. The most similar distractor is in the top right hand corner of the array

with both the name and the dose differing from the target. The second most similar distractor is in the bottom right hand corner of the array with the name, dose, and band of the image differing to the target. The least similar distractor is in the top left hand corner of the array and differs in band, dose, name and other.

In the target absent arrays, arrays contained four distractors that varied on their similarity to the target. The distractors were varied on the same dimensions as the target present arrays. See Figure 3.3 for an example of a target absent array.



*Figure 3.3.* An example of a target absent array for the same target present in Figure 3.1. The most similar distractor is in the bottom right hand corner with only the dose of the medication differing from the target. The second most similar distractor is in the bottom right hand corner of the array with only the dose and name of the medication differing from the target. The third most similar distractor is in the top right hand corner of the array with the dose, name and band of the medication differing to the target. The least similar distractor is in the top left hand corner of the array with the name, dose, band and shape differing from the target.

Two sets of arrays were used for Experiments 1B and 1C and the order of the arrays were counterbalanced across participants. Participants saw a different set of arrays for Experiments 1B and 1C. Each set had 32 arrays with 16 target present arrays and 16 target absent arrays. In the second set, 50% of the items that were present in set one were absent and 50% of the items that were absent in set one were present. The location of the target was randomised both across and between sets of arrays. Participants could not rely on their memory of the previous study to determine whether the target is present or absent in the

array, or the location of the target. The order that participants saw the two sets of arrays were counter balanced across participants.

### Procedure

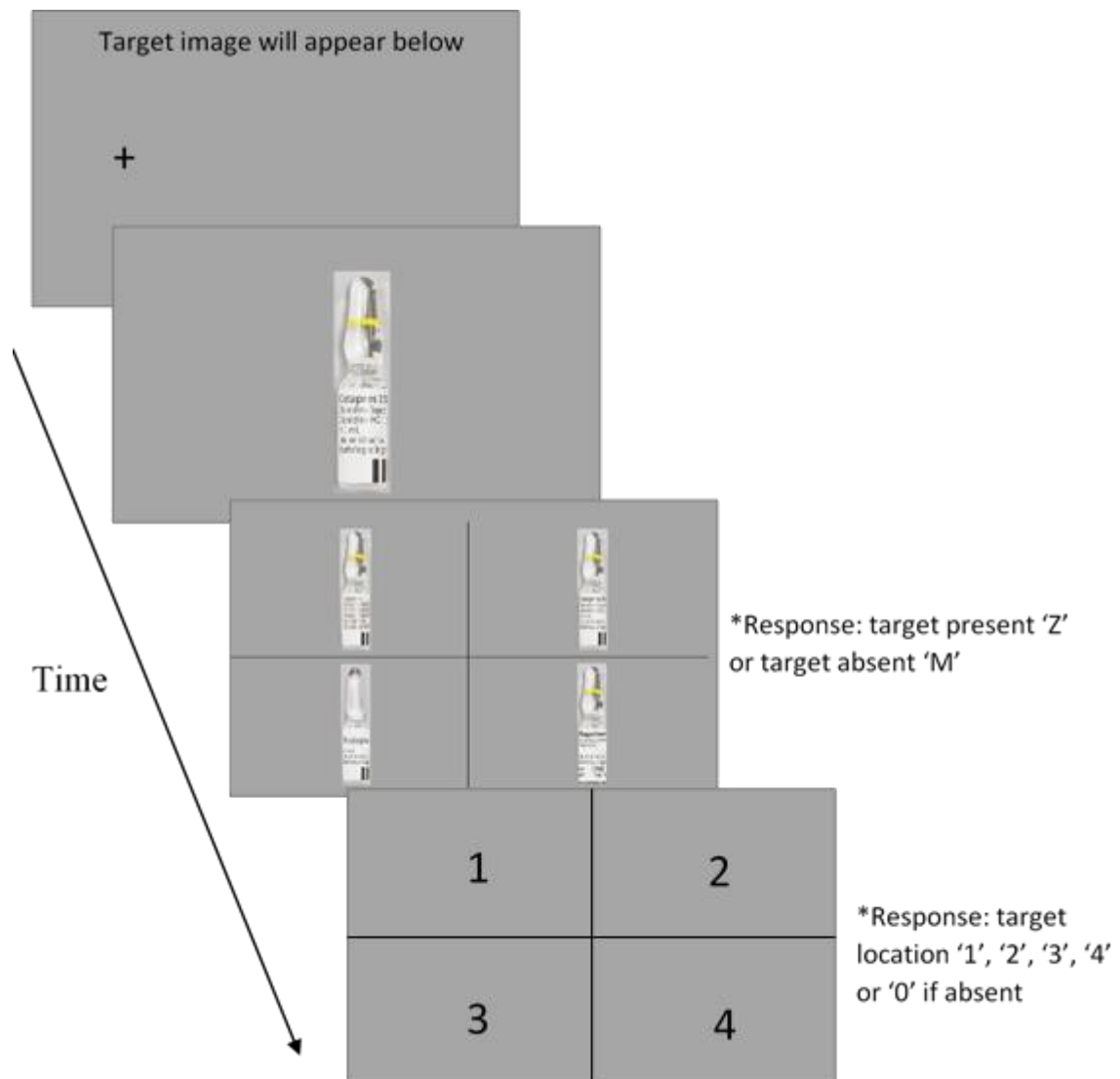


Figure 3.4. A diagram of the series of events within each trial of the experiment. The fixation cross was presented for two seconds

Figure 3.4 presents a diagram of a trial, each trial started with a centrally located fixation cross pertaining to  $0.96^\circ$  visual angle. Above the fixation cross were the words “Target image will appear below”. This screen was presented for three seconds. Following the presentation of the fixation cross screen, participants viewed a centrally located target image for two seconds following which the array was presented. Participants were asked to make a judgement on whether or not the target was present in the array. If participants thought the target was present in the array they pressed the ‘Z’ key, if participants thought the target was absent in the array they pressed the ‘M’ key. The array was presented until the

participants made their judgement. Following this judgement participants were presented with a screen with the four quadrants of the screen numbered from 1-4. Participants selected the number that they believed corresponded to the target's location from the array. Participants pressed the '0' key if they believed the target was absent in the array. Participants were instructed to respond as quickly and as accurately as possible. Before starting the medical version of the experiment participants completed 10 practice trials. Practice trials used the same layout as medical trials; however they included images of scenery rather than medications. Scenery was used throughout the practice trials to minimise any practice effects that may occur when viewing medications, e.g. focussing on specific label features such as name or dose. The researcher monitored the performance of the participant during the practice trials to insure that there was no confusion and to ensure that participants were correctly responding to the task. See Appendix G for an example of a practice trial. Upon completion of the practice trials participants had the opportunity to ask questions about the task before moving onto medication trials. After participants had completed the 32 medication trials participants were instructed to move away from the screen.

**Instructions.** Participants were presented with instructions both on screen and by the experimenter. The instructions on screen were as follows:

"Welcome to the experiment. You will be presented with a target item, you will then see an array of four items. It is your job to say if the target is present or absent. Press the 'Z' key if the target is present, press the 'M' key if the target is absent"

"You will then see an array of numbers you need to indicate (using the number in the box) where the target item was located in the array"

"Remember 'Z' = present, 'M' = absent. Please make all responses as quickly and as accurately as possible. Remember to keep your head as still as possible. Any questions?"

### **Data Analysis**

Overall accuracy was calculated separately for target present and target absent trials by counting the total number of trials (of 16) in each category on which the participant correctly indicated whether the target was present. In relation to signal detection theory accuracy on target present trials represented a hit, accuracy on target absent trials represented a correct rejection. The number of misses was calculated for each individual by taking the total number of target absent trials (16) and subtracting the hits. To calculate the number of false alarms the overall accuracy on target absent trials was subtracted from the total number of target absent trials (16). From these numbers individual discriminability ( $d'$ ) and criterion



values (C) were calculated. The calculations for  $d'$  and C are as follows (H = hit rate and FA = False alarms. To avoid ceiling or floor values each 0.25 was added to each cell before calculating  $d'$  and C):

$$d' = z(H) - z(FA)$$

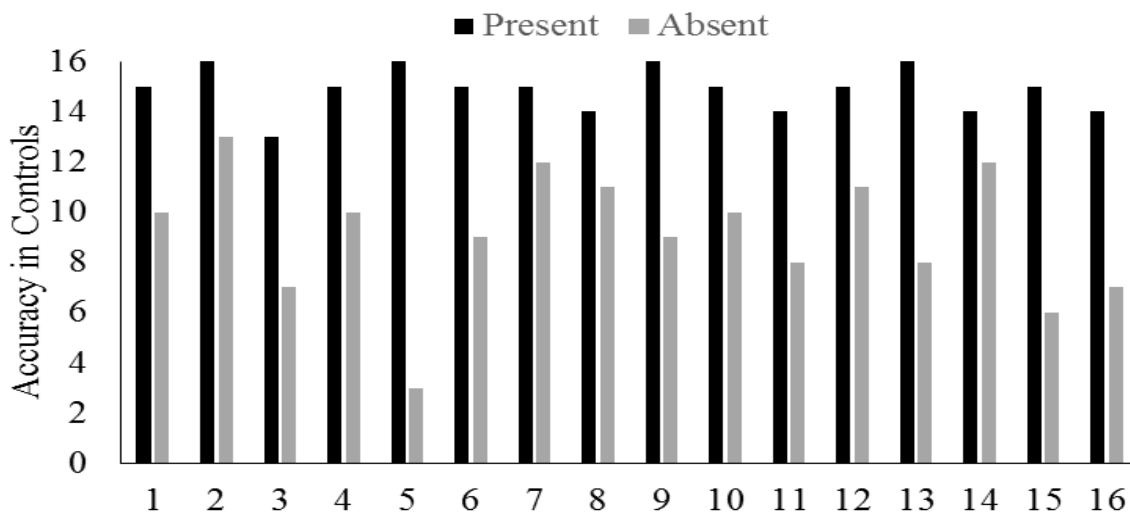
$$C = -0.5 \times (z(H) + z(FA))$$

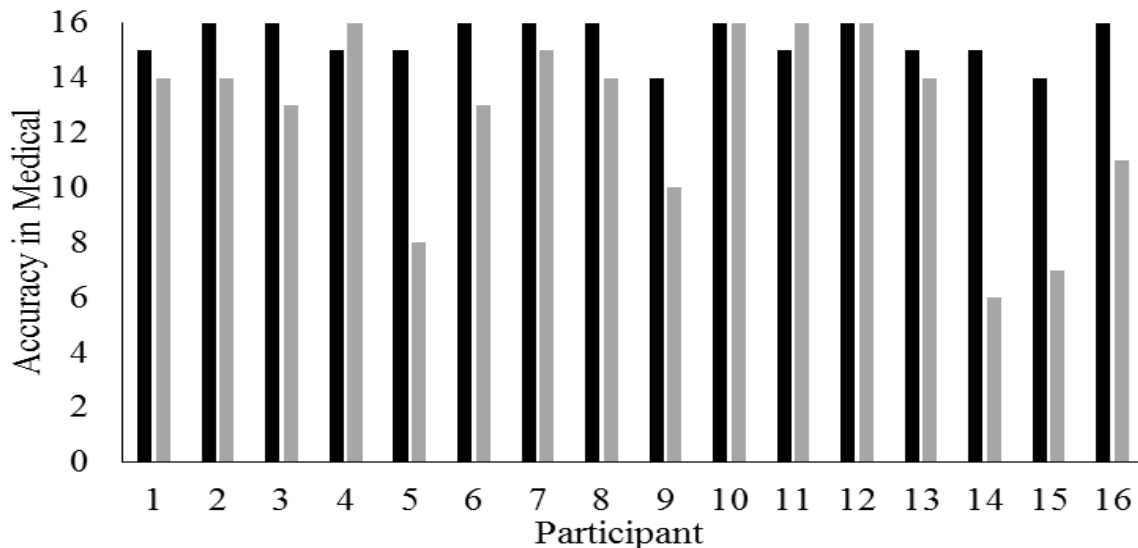
An independent samples t-test was used to compare the difference in the discriminability index between control and medical participants. Tests of normality (Saphiro Wilk) revealed the data for criterion in control participants were non-normal ( $p = .045$ ) and log transformations failed to normalise the data. Therefore a Mann-Whitney U test was used to determine whether there was a difference in criterion levels between control and medical professionals. All other data were normal. Therefore an independent samples t-test was used to assess the differences in discriminability between groups.

To assess the breakdown of errors due to labelling and packaging, every error that was made when a participant incorrectly selected a distractor from an array was assessed. This breakdown was achieved by categorising each array according to the features that differed between the target and that distractor. For example, some trials included a distractor that was identical to the target except the distractor had a different name; we calculated the number of times such a distractor was selected, the number of trials on which they were present, and therefore the percentage of times distractors differing only in name were selected when present. These analyses were conducted separately for target present and target absent trials and then separated out according to errors on ampoule and bottle images.

## Results and Discussion

### Overall Accuracy





*Figure 3.5.* The number of trials (of 16) on which participants made correct target present and absent judgements for control (top panel) and medical (bottom panel) participants. Black bars correspond to the accuracy on target present trials and grey bars correspond to accuracy on target absent trials.

Figure 3.5 presents a comparison between controls and medical participants for the overall accuracy at indicating whether or not the target was present out of 16 on the target present and target absent trials. The most noticeable difference between groups in overall accuracy was on the target absent trials (grey bars) with controls making more errors (false alarms) than medical participants. Both groups of participants were more accurate on the target present trials compared to the target absent trials. The overall accuracy of medical participants was higher than that of controls and medical participants made very few errors on the target present trials. The above findings are consistent with Badeaux (2015) who found that participants were less accurate on target absent trials. The current study displayed a higher absolute rate of false alarms than Badeaux's study. This difference in rate of false alarms could be due to the fact that Badeaux's arrays only had one distractor that was similar to the target whereas the current study included distractors that varied with increasing similarity to the target medication.

Due to the low rate of accuracy on the target absent trials the high rates of accuracy on the target present trials should be interpreted with caution. By looking at overall accuracy alone it is difficult to determine whether participants were accurate on the target present trials because they correctly determined that the target was present or because of response bias. Therefore, signal detection theory analyses were conducted.

### **Signal Detection Theory Analyses**

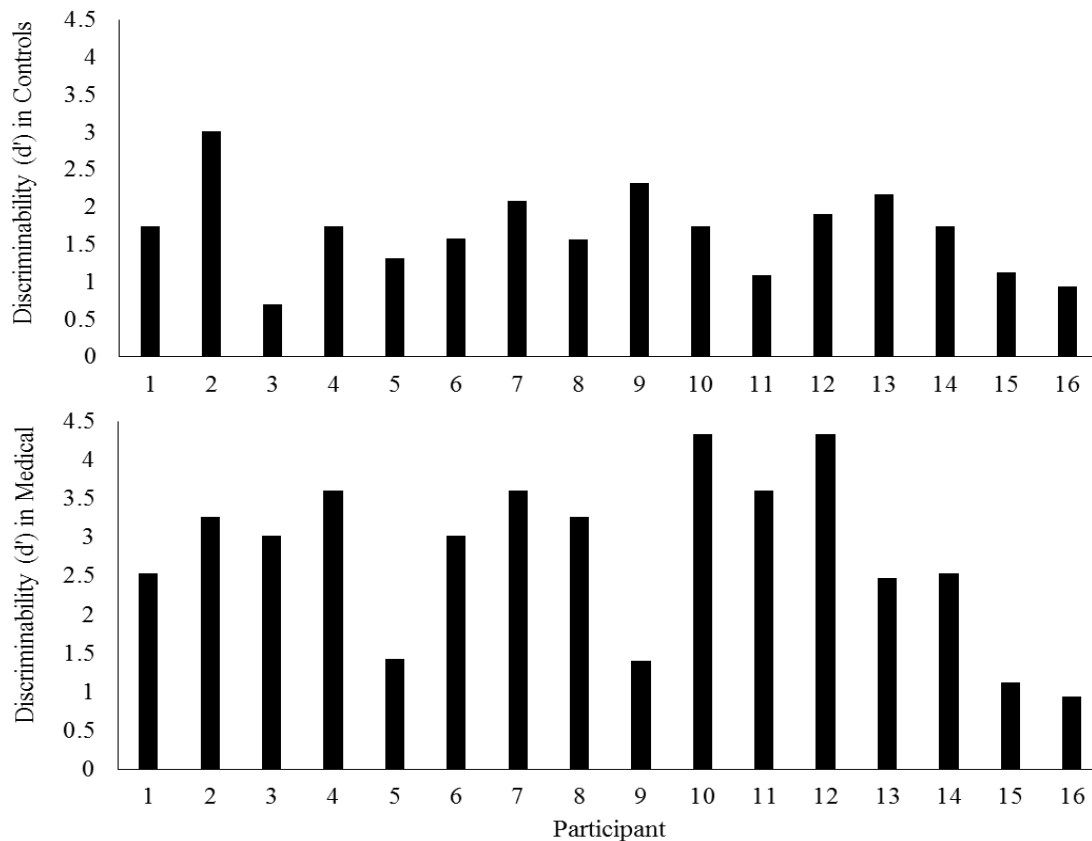


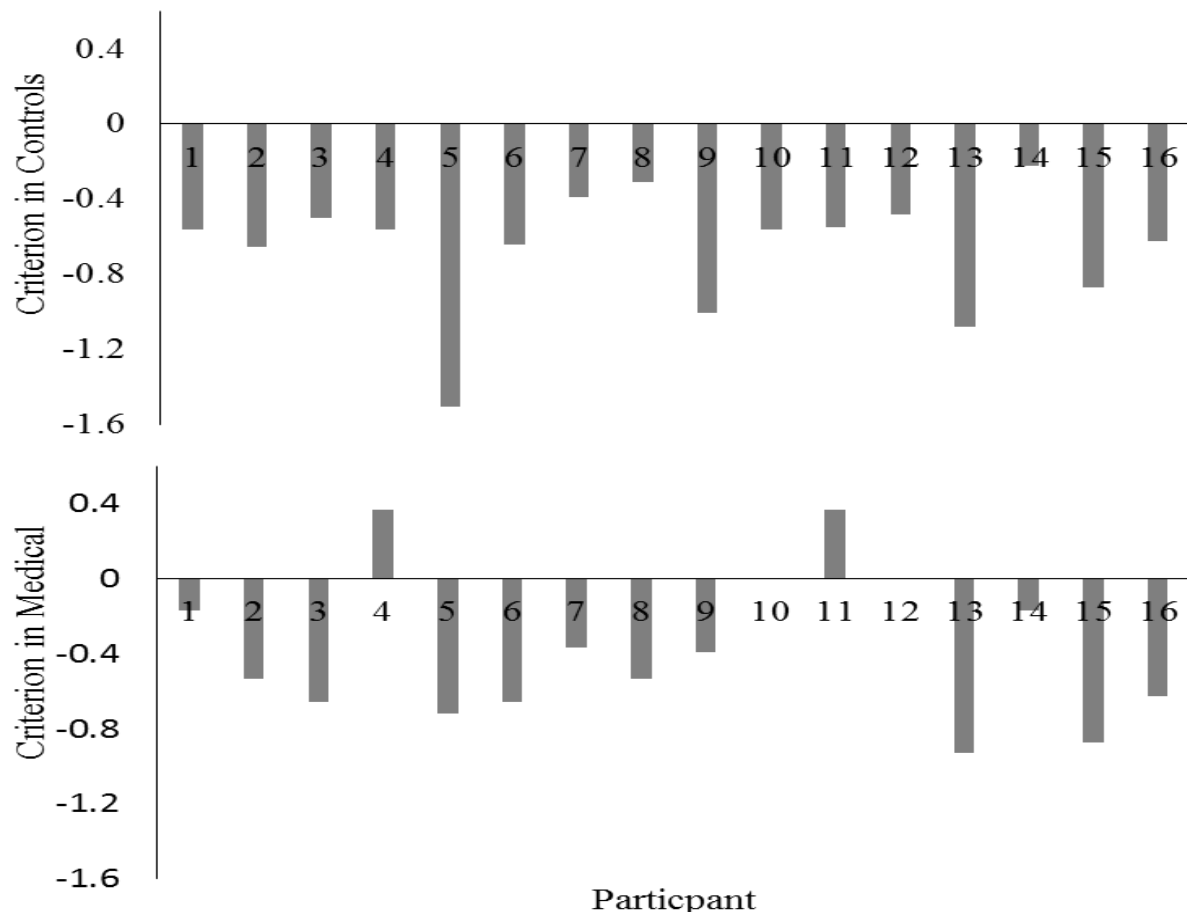
Figure 3.6. Bar graphs representing the discriminability index of control (top panel) and medical participants (bottom panel). Numbers closer to 4.5 indicate near perfect discriminability and numbers closer to 0 represent that discriminability was near or at chance.

Figure 3.6 presents a comparison of the discriminability index of medical and control participants. Control participants have lower discriminability indexes than medical professionals. Two of the 16 medication professionals demonstrated perfect or near perfect discriminability. Four of the 16 medical professionals had low rates of discriminability. Comparatively, none of the control participants exhibited perfect discriminability and ten displayed low discriminability.

Consistent with the pattern observed in Figure 3.6 an independent samples t-test revealed that the control discriminability index ( $M = 1.68$ ,  $SD = 0.58$ ) was significantly lower than the discriminability index of medical professionals ( $M = 2.78$ ,  $SD = 1.08$ ),  $t(30) = 3.61$ ,  $p = .014$ ,  $d = 1.27$ . This result indicates that medical participants were significantly better at discriminating whether or not the target was present or absent in the array than the control participants.

These results imply that medical experience increases the ability of an individual to correctly discriminate whether or not a medication is present from a selection. From the participant information, there are not any clear patterns evident in either the profession

(nurse, doctor or technician) or years of experience in the medical participants with perfect or low discriminability. The individual with the greatest experience (participant three with 37 years' experience) demonstrated the same level of discriminability as the individual with the least experience (participant two with four years' experience). These observations indicate that regardless of the type or length of experience medical experience tends to help individuals when determining whether or not a target is present or absent.



*Figure 3.7.* The criterion level of control participants (top panel) and medical participants (bottom panel). Negative numbers indicate a criterion level set towards responding that the target is present, a zero indicates that participants showed no bias, positive numbers indicate that the criterion level was set towards responding that the target was absent.

Figure 3.7 presents a comparison of the criterion level of control and medical participants. On an individual level some of the medical professionals were more conservative in their judgements (i.e. they were less biased towards responding that the target was present) than controls, however the overall difference in criterion levels is not consistent between groups. Twelve of the 16 medical professionals showed a criterion level that was within a similar range of the control participants. Only four medical professionals displayed

any clear difference in criterion level to controls with two showing no evidence of bias and two participants displaying a bias in the reverse direction of the rest of the participants (i.e. towards responding that the target was absent).

A Mann-Whitney U test was used to determine whether there was a significant difference between the criterion levels of control ( $Mdn = -0.56$ ) and medical participants ( $Mdn = -0.46$ ). A non-significant result was found,  $U = 85.00$ ,  $p = .105$ , indicating that controls participants and medical professionals displayed no difference in their level of bias.

These results imply that medical experience does not alter the bias of an individual to say whether or not a target is present in an array. This result is not consistent with the results seen for the differences between groups in the discriminability indexes. This difference implies that differences in overall accuracy between groups is due to an increased ability of medical participants to correctly discriminate the target, regardless of bias.

### Breakdown Analysis of Error

Errors were broken down into sub-types in order to more completely characterise the types of errors participants made when determining whether the target was present or absent and in selecting the target from the array.

**Target present trials.** There were two main types of errors that could be made on a trial on which the target was present. One possible error was to incorrectly indicate that the target was absent (i.e. a miss). Another possible error was to correctly indicate that the target was present but then fail to select the target from array selecting a distractor instead. Control participants made 131 total errors on target present trials. Participants responded that the target was absent in the array for 12.98% of errors. Participants selected the most similar distractor on 34.35% of the total 131 errors, the second most similar distractor on 23.66% of errors and the least similar distractor on 29.01% of errors. The high rate of errors made where participants selected a distractor instead of responding that the target was absent reflects the bias seen in Figure 3.7 whereby participants tended to respond that the target was present.

Table 3.1.

*Break down of the 114 times control participants incorrectly selected a distractor on target present trials*

Change	error	total	%	ampoule			bottle		
				error	total	%	error	total	%
DT	8	16	50.00%	0	8	0.00%	8	8	100.00%

D	4	24	16.67%	1	8	12.50%	3	16	18.75%
ND	23	144	15.97%	15	96	15.63%	8	48	16.67%
NDTO	38	240	15.83%	29	120	24.17%	9	120	7.50%
N	24	168	14.29%	8	80	10.00%	16	88	18.18%
NO	14	104	13.46%	5	48	10.42%	9	56	16.07%
DO	2	16	12.50%	0	0	0.00%	2	16	12.50%
NT	1	24	4.17%	0	0	0.00%	1	24	4.17%
NDO	0	0	0.00%	0	0	0.00%	0	0	0.00%
NDT	0	24	0.00%	0	24	0.00%	0	0	0.00%
NTO	0	8	0.00%	0	0	0.00%	0	8	0.00%

*Note.* Change column represents the type and combination of ways that the target differed from the distractor images, N = Name, D = Dose, T = the top of the medication Band for ampoules or Cap for bottles, and O = Other. Error column represents the total number of times all participants selected a distractor with the change. Total column represents the total opportunities all participants could have selected a distractor with the change. % represents the total percentage of opportunities where error was made.

Table 3.1 presents a breakdown of the types of errors made when control participants incorrectly selected a distractor medication on target present trials. It is important to note that while some types of distractor were selected a high number of times compared to other, this distractor might also have been presented more often. For example, in the table above there were 38 errors on distractors that were entirely different to the target image. Given that there was a distractor of this type in almost all of the arrays, the number of possible times all participants could have selected that distractor was 240 times. Therefore, it is important to look at the % column that gives an indication of the percentage of times an error was made given the possible total opportunity of that error occurring.

The most common type of error was when only the dose and top of the medication was altered (as indicated by the DT row in the column). All of these errors were made on bottle images. The second most common type of error was made when only the dose of the medication was changed and the majority of these errors occurred in bottle images. These results are consistent with the eye data that found that controls did not attend to the cap of the medication and paid more attention to the name and other properties of the medication in comparison to the dose of the medication.

The third most common type of error was made when only the name and dose of the

medication differed from the target. The percentage of these errors indicate that they were made relatively equally across ampoule and bottle images. In part these results were consistent with the findings of Study 1A because participants attended to the dose of the medication less than the other information. However, it was found that control participants attended to the name information more than the dose or band/cap of the medication. A similar number of errors were made when changes were made to the name and name and other properties of the medication. A possible explanation for this rate of error could be due to name similarity.

The rate of error when the target was completely different to the distractor was similar to the rate of error made when the name and dose changed and higher than the rate of error for just the name, name and other, dose and other, and dose and top. This indicates that participants were more likely to select a distractor that was completely different to the target than a distractor that contained one or more similarities to the distractor.

Medical participants made 16 errors on target present trials. Medical participants responded that the target was absent in the array (i.e. a miss) for 50% of the total errors. Medical participants selected the most similar distractor for 43.75% of the 16 total errors. Participants selected the second most similar distractor on 6.25% of the 16 errors and did not select the least similar distractor for any of the errors.

Table 3.2

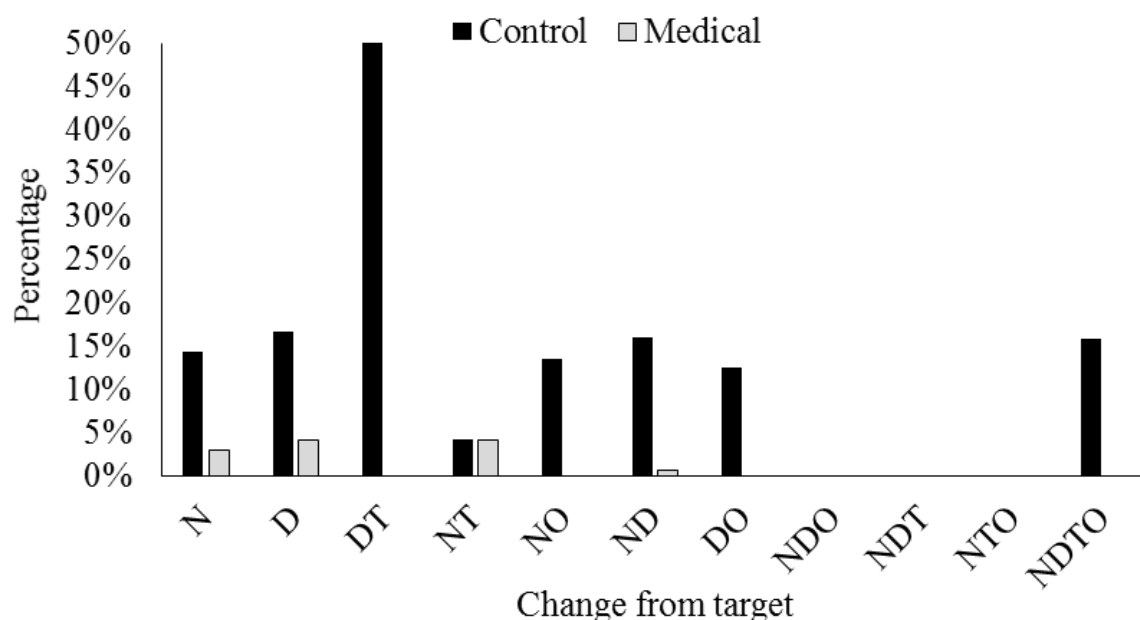
*Break down of the eight times medical participants incorrectly selected a distractor on target present trials*

Change				ampoule			bottle		
	error	total	%	error	total	%	error	total	%
D	1	24	4.17%	0	8	0.00%	1	16	6.25%
NT	1	24	4.17%	0	0	0.00%	1	24	4.17%
N	5	168	2.98%	0	80	0.00%	5	88	5.68%
ND	1	144	0.69%	0	96	0.00%	1	48	2.08%
DT	0	16	0.00%	0	8	0.00%	0	8	0.00%
NO	0	104	0.00%	0	48	0.00%	0	56	0.00%
DO	0	16	0.00%	0	0	0.00%	0	16	0.00%
NDT	0	24	0.00%	0	24	0.00%	0	0	0.00%
NDTO	0	240	0.00%	0	120	0.00%	0	120	0.00%

NTO	0	8	0.00%	0	0	0.00%	0	8	0.00%
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*Note.* Change column represents the type and combination of ways that the target differed from the distractor images, N = Name, D = Dose, T = the top of the medication Band for ampoules or Cap for bottles, and O = Other. For example, if Dose was the only feature changed (D) then Name, Top, and Other features of the distractor selected were identical to the target. Error column represents the total number of times all participants selected a distractor with the change. Total column represents the total opportunities all participants could have selected a distractor with the change. % represents the total percentage of opportunities where error was made.

Table 3.2 presents the types of errors made when medical participants incorrectly selected a distractor on target present trials. Consistent with their high level of discriminability it is evident that medical participants made very few errors on target present trials. Looking at the percentage of opportunities for error, the most common type of error made by medical participants was when the dose and both the name and top of the medication differed to the target medication and all errors were made on bottle images. Due to the small number of errors it is difficult to determine what these errors could mean in an applied setting and all conclusions should be interpreted with caution.



*Figure 3.8.* The percentage of total opportunity when errors were made on target present trials for control (black bars) and medical (light grey bars) participants across all possible error types.

Figure 3.8 presents a comparison between control and medical participants on the



percentage of opportunities where error was made on the target present trials. Consistent with the findings for discriminability control participants made more errors on target present trials compared to medical professionals. No medical participants made errors on distractors where only the dose and top of the medication was changed, and they were less likely than control participants to select distractors differing from the target only in dose. This could be due to the finding in Study 1A that medical participants fixated significantly longer on the dose of the medication compared to control participants.

**Target absent trials.** There was only one type of error that could be made on target present trials. This error is when participants incorrectly responded that the target was absent in the array and selected a distractor image (i.e. a false alarm). Control participants made a total of 111 errors on target absent trials. Participants selected the most similar distractor on 43.24% of errors, the second most similar distractor on 29.73% of errors, the third most similar distractor on 11.71% of errors, and the least similar distractor on 15.32% of errors. The high rate of errors reflects the fact that participants tended to respond that the target was present in the array.

Table 3.3

*Break down of the 111 times control participants incorrectly selected a distractor on target absent trials*

Change				ampoule			bottle		
	error	total	%	error	total	%	error	total	%
D	38	160	23.75%	19	80	23.75%	19	80	23.75%
N	32	168	19.05%	7	72	9.72%	25	96	26.04%
DT	5	32	15.63%	1	16	6.25%	4	16	25.00%
NDT	5	32	15.63%	5	16	31.25%	0	16	0.00%
DO	2	24	8.33%	0	0	0.00%	2	24	8.33%
NDTO	17	240	7.08%	11	120	9.17%	6	120	5.00%
ND	5	104	4.81%	5	56	8.93%	0	48	0.00%
NT	1	24	4.17%	1	16	6.25%	0	8	0.00%
NO	6	224	2.68%	5	136	3.68%	1	88	1.14%
NDO	0	8	0.00%	0	0	0.00%	0	8	0.00%
NTO	0	8	0.00%	0	0	0.00%	0	8	0.00%

*Note.* Change column represents the type and combination of ways that the target differed from the distractor images, N = Name, D = Dose, T = the top of the medication Band for

ampoules or Cap for bottles, and O = Other. For example, if Dose was the only feature changed (D) then Name, Top, and Other features of the distractor selected were identical to the target. Error column represents the total number of times all participants selected a distractor with the change. Total column represents the total opportunities all participants could have selected a distractor with the change. % represents the total percentage of opportunities where error was made.

Table 3.3 presents a breakdown of the type of errors made when control participants incorrectly selected a distractor on target absent trials. Consistent with the pattern of fixations whereby control participants fixated more often on the name and other properties of the medication, the most common type of error was made when only the dose differed from the target medication. This pattern of error occurred equally in bottle and ampoule images. In contrast to the predictions made from the eye data the second largest source of error were distractor images that differed from the target only in name. The majority of these errors were made in the bottle images, which could be explained by the finding from Study 1A that control participants fixated significantly longer and more often on the other AOI than the name of the medication. The relatively small percentage of error when both the name and other properties were changed is consistent with this possible explanation of error.

Equal rates of error were made when the dose and top and the name, dose, and top were changed from the target. Similar to the pattern observed in the target present trials, bottles accounted for the majority of errors when the dose and top of the medication were changed. However when the name, dose, and top of the medication were changed more errors were made in ampoule images. This result is not consistent with the pattern of fixations whereby there were more fixations on the bands of the ampoules than the cap of the bottles. Based on the percentage of errors made when just the name and dose were changed it is not just the name and dose changes that are driving this rate of error for NDT.

Medical participants made a total of 53 errors on target absent trials. Participants selected the most similar distractor on 77.36% of errors, the second most similar distractor on 16.98% of errors, the third most similar distractor on 3.77% of errors, and the least similar distractor on 1.89% of errors.

Table 3.4

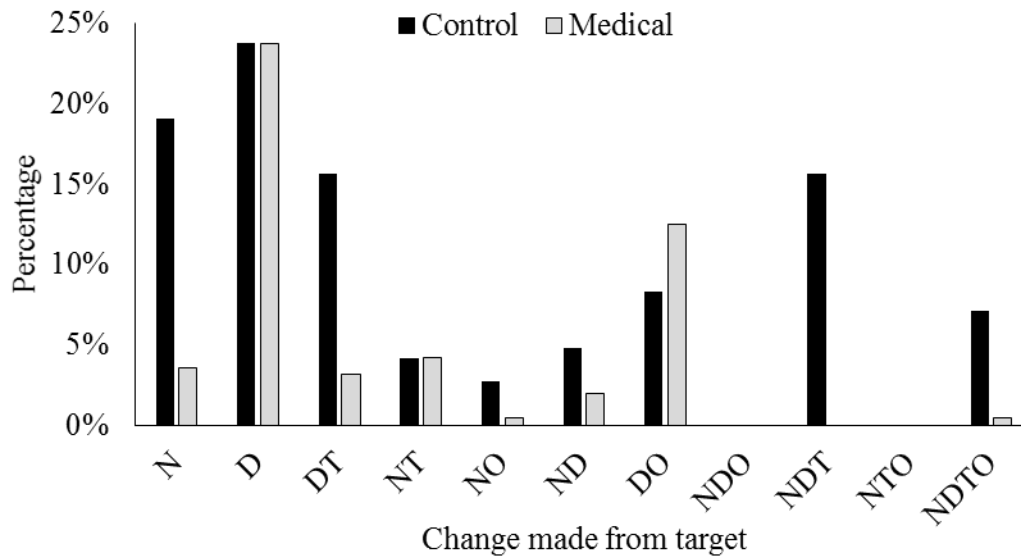
*Break down of the 53 times medical participants incorrectly selected a distractor on target absent trials*

	ampoule	bottle
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Change	error	total	%	error	total	%	error	total	%
D	38	160	23.75%	16	80	20.00%	22	80	27.50%
DO	3	24	12.50%	0	0	0.00%	3	24	12.50%
NT	1	24	4.17%	1	16	6.25%	0	8	0.00%
N	6	168	3.57%	1	72	1.39%	5	96	5.21%
DT	1	32	3.13%	0	16	0.00%	1	16	6.25%
ND	2	104	1.92%	1	56	1.79%	1	48	2.08%
NO	1	224	0.45%	1	136	0.74%	0	88	0.00%
NDTO	1	240	0.42%	1	120	0.83%	0	120	0.00%
NDO	0	8	0.00%	0	0	0.00%	0	8	0.00%
NDT	0	32	0.00%	0	16	0.00%	0	16	0.00%
NTO	0	8	0.00%	0	0	0.00%	0	8	0.00%

*Note.* Change column represents the type and combination of ways that the target differed from the distractor images, N = Name, D = Dose, T = the top of the medication Band for ampoules or Cap for bottles, and O = Other. For example, if Dose was the only feature changed (D) then Name, Top, and Other features of the distractor selected were identical to the target. Error column represents the total number of times all participants selected a distractor with the change. Total column represents the total opportunities all participants could have selected a distractor with the change. % represents the total percentage of opportunities where error was made.

Table 3.4 presents the types of errors made when medical participants incorrectly selected a distractor on target absent trials. Similar to control participants'; medical participants made the most errors on distractors where the dose of the medication differed from the target. These findings could be due to that the fact that medical participants attended more to the name than the dose of the medication (as in Study 1A). Furthermore, the relatively low percentage of errors on distractors that contained a different name was consistent with this finding from Study 1A. It is possible that medical experience increases the likelihood of a medical professional to fixate on the name of the medication when selecting a medication. Since the eye data from Study 1A were collected without the task requirement of selecting a medication it could be possible that medical professionals change their patterns of fixations and focus more on the name of the medication than the other information.



*Figure 3.9.* The percent of total opportunity when errors were made on target absent trials for control (black bars) and medical (light grey bars) participants across all possible error types.

Figure 3.9 presents a comparison of the types of errors both groups of participants made on the different types of distractors. Control and medical participants made the same number of errors on distractors where only the dose differed to the target. Given the differences between groups in Study 1A, whereby medical fixated for longer (and more often in ampoules) on the dose of the medication than controls, this finding is unexpected. A possible explanation is that the dose of the medication is often quite small and it is possible that the size of the change meant that it was difficult to detect.

### Conclusion

Overall the results of this study indicate that medical professionals compared to control participants were better at discriminating whether or not the target was present in the array. There was no difference between the criterion levels of control or medical participants. The negative criterion levels for each group demonstrated that participants were more likely to respond that the target was presented which resulted in high rate of false alarms. This was also evident from the high rate of bias in the majority of control participants and some medical participants. Control participants were more likely to make errors when the dose or name of the medication was the only change from the target. Medical participants were more likely to make errors when the dose of the medication differed from the target.

#### **Chapter Four: Study 1C – Target Identification with Divided Attention**

As previously mentioned there are a large number of environmental stimuli, distractions, and noise in an operating theatre. Given the task requirements of keeping a patient alive and well during a surgery, it is obvious that the medication selection process rarely happens in a calm distraction-free environment where the full focus of the individual is on the task at hand. The target identification experiment in study 1B was a good first look at what can happen during medication selection however; this task did not factor in the involvement of distracting factors during medication selection. The primary goal of study 1C was to assess the role of divided attention on medication selection. The same target identification procedure used in Study 1B was used with the addition of an integrated divided attention task.

Divided attention tasks have been shown to reduce accuracy in previous studies (Ghazanfar & Cook, 2015; Stevenson et al., 2013; Kataoka et al., 2011). Findings from Ghazanfar and Cook and Kataoka et al. show that individuals new to medical training are more likely to make errors in conditions of divided attention compared to experienced medical professionals. Stevenson et al. (2013) demonstrated that divided attention tasks of different attentional load can have different effects on accuracy, with greater attentional load resulting in more errors.

Similar to the divided attention task used by Stevenson et al. (2013), the divided attention task in this study had two main levels. Stevenson et al. presented participants with a string of white letters on a screen and participants responded when they saw a red letter whilst completing an auditory medical task. As the intention was to provide two simultaneously occurring tasks, it was desirable to intertwine the divided attention task with the target identification task and thus create an environment more similar to a medical environment it was not feasible to use the same task. Instead participants saw a row of letters and were instructed to remember them in the order they were presented. In a later screen participants saw the same number of dashes as they had previously seen letters with one dash highlighted in red with an arrow pointing to it. Participants responded with the letter that they believed was in that position. Piloting of the divided attention task revealed that five and seven letters were sufficient to provide a reliable difference between accurate recall on the task without placing performance on the task at ceiling or floor.

In addition to assessing the role of divided attention on accuracy the goals of study 1C were similar to that of study 1B. That is, this study assessed the effect of two divided

attention conditions (five and seven letters) on discriminability and bias. Further, this study assessed the breakdown of error and determined what labelling factors led to error.

### **Method**

#### **Participants**

Participants were the same 16 medical professionals and 16 controls as used in the passive viewing experiment.

#### **Materials**

Targets were images of 32 injectable medications taken at Wellington Hospital. The targets were the same as those in the target identification experiment (Study 1B). The set of arrays that was not used in Study 1B for a particular participant was used in Study 1C for that participant. The same computer and specifications as used in studies 1A and 1B were used throughout Study 1C.

#### **Procedure**

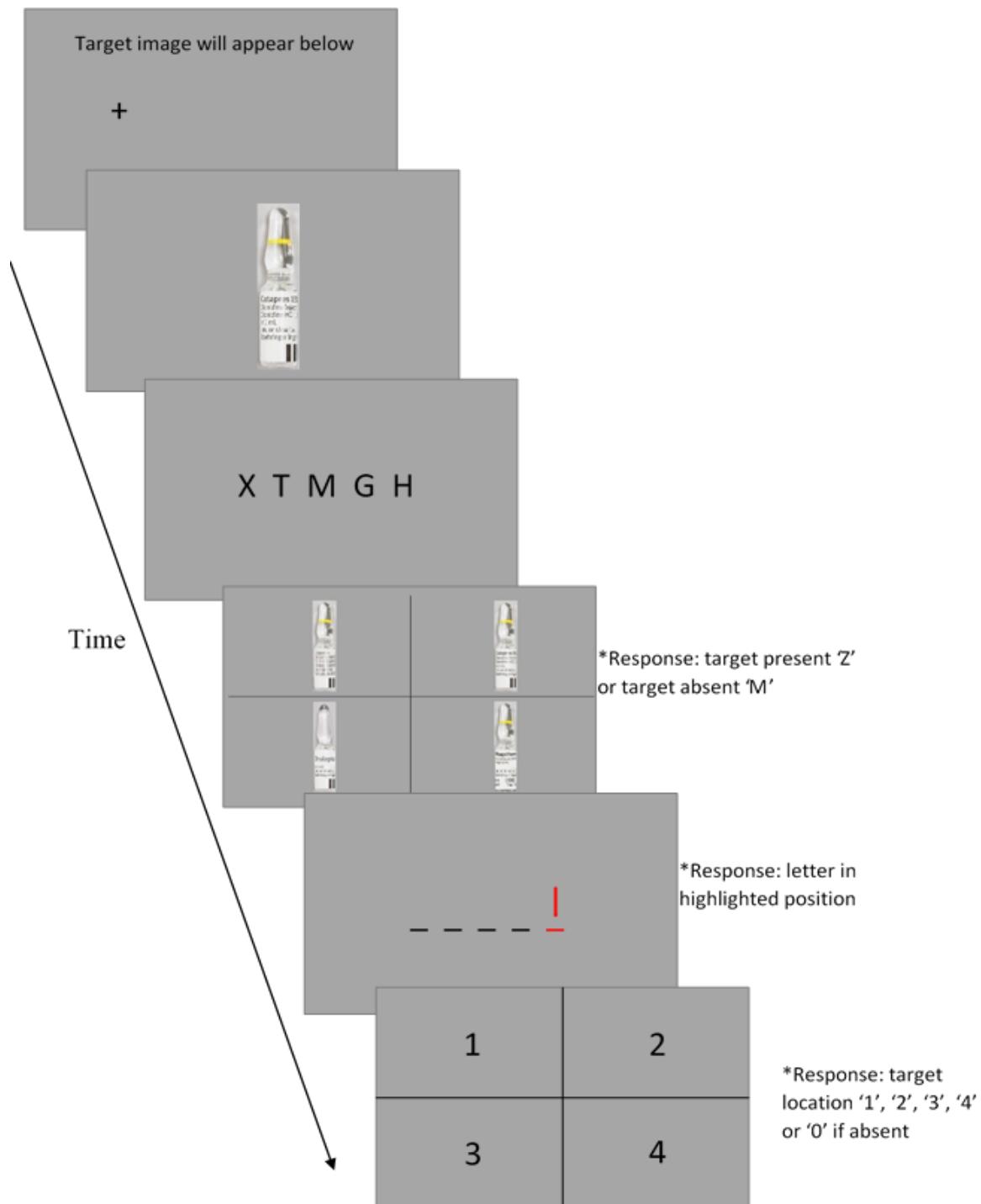


Figure 4.1. A diagram of a trial for study 1C.

Each trial started with a centrally located fixation cross pertaining to  $0.96^\circ$  visual angle. Participants were presented with a target image for two seconds. Following this presentation participants were presented with either five or seven letters for seven seconds. Sixteen trials had five letters and 16 had seven letters, and these randomised across the course of the experiment. Participants were then presented with the array and made a judgement on whether or not the target was present in the array. Responding was the same as Experiment

1B with 'Z' indicating the target was absent in the array and 'M' indicating the target was present in the array. Following this judgement a divided attention recall screen was presented. The recall screen contained a series of either five or seven dashes (depending on the number of letters presented in the previous screen), one of which was red with a red arrow above it. Participants entered the letter that they believed was in the highlighted location. Participants were then presented with a screen with the four quadrants of the screen numbered from 1-4. Participants selected the number that they believed corresponded to the target's location in the array. If participants did not think the target was present in the array they were instructed to select the '0' key. Participants were instructed to respond as quickly and accurately as possible and were told that accuracy was important on both tasks. Throughout the experiment participants received feedback on their performance on the divided attention task in the form of a 'correct' or 'incorrect' message. Participants completed ten practice trials containing targets and distractors of scenery before moving onto the medical trials. A researcher monitored participants' performance on the task throughout the practice trials and if the feedback was always showing the message 'incorrect' participants were reminded that it was important to be accurate on both tasks. After participants had completed 32 medical trials participants were instructed to move away from the screen.

**Instructions.** Participants received instructions on screen and the same instructions, with one addition, were read out loud by the experimenter. The instructions were as follows, the italics represent the information that was only presented verbally to the participant:

"Welcome to the experiment. You will be presented with a target item. You need to remember this item. Later you will see an array of four items. It is your job to say if the target is present or absent. Press the 'Z' key if the target is present. Press the 'M' key if the target is absent."

"Later, you will see an array of numbers you need to indicate (using the number in the box) where the target item was located in the array"

"You will see a sequence of letters. You need to remember the letters in the order they were presented"

"Later you will be given a probe and you must respond with the letter that was in that position"

"Remember 'Z' = present, 'M' = absent. Please make all responses as quickly and as accurately as possible. *Keep in mind that it is important to be accurate on both tasks with that in mind you will receive feedback on your performance on the letter task.* Remember to keep your head as still as possible. Any questions?"



The order of the target identification experiment and divided-attention experiment were counterbalanced using a Latin square design across participants. Participants took a self-timed break in between each experiment. Once all three experiments were completed medical participants completed a five minute survey about their years of medical experience, type of medical experience, whether they had selected an incorrect medication in the past, and how they felt about labelling. Following completion of the experiment participants were verbally debriefed, given a movie voucher, and thanked for their time.

### **Data analysis**

Primary analysis was similar to that of Study 1B with the addition of categorisation of accuracy into the five-letter and seven-letter divided attention conditions. The data for letter recall on the target present and absent conditions when there were five letters in the divided attention task were non-normal as determined by a Saphiro Wilk test ( $ps < .05$ ). Ideally, to compare the influence of target (present, absent) on letter recall (5, 7) between medical and controls a mixed repeated measures ANOVA would be conducted; however, there exists no non-parametric equivalent. Therefore, a two-way repeated measures ANOVA was conducted between the control participants' letter accuracy under the two conditions of target (present, absent) and letter (5, 7). A Friedman test was conducted to compare the differences in letter recall for medical professionals. To compare between the groups, a Wilcoxon-Signed Rank test was conducted for the control and medical participants on the absent five letter and present five letter conditions. An independent samples t-test was used to compare between groups on the absent seven letter and present seven letter conditions.

The data for discriminability on the five and seven letter conditions were all normally distributed as determined by a Saphiro Wilk test ( $ps > .05$ ). Therefore, a mixed ANOVA was used to compare the differences between control and medical participants on discriminability for the five and seven letter conditions.

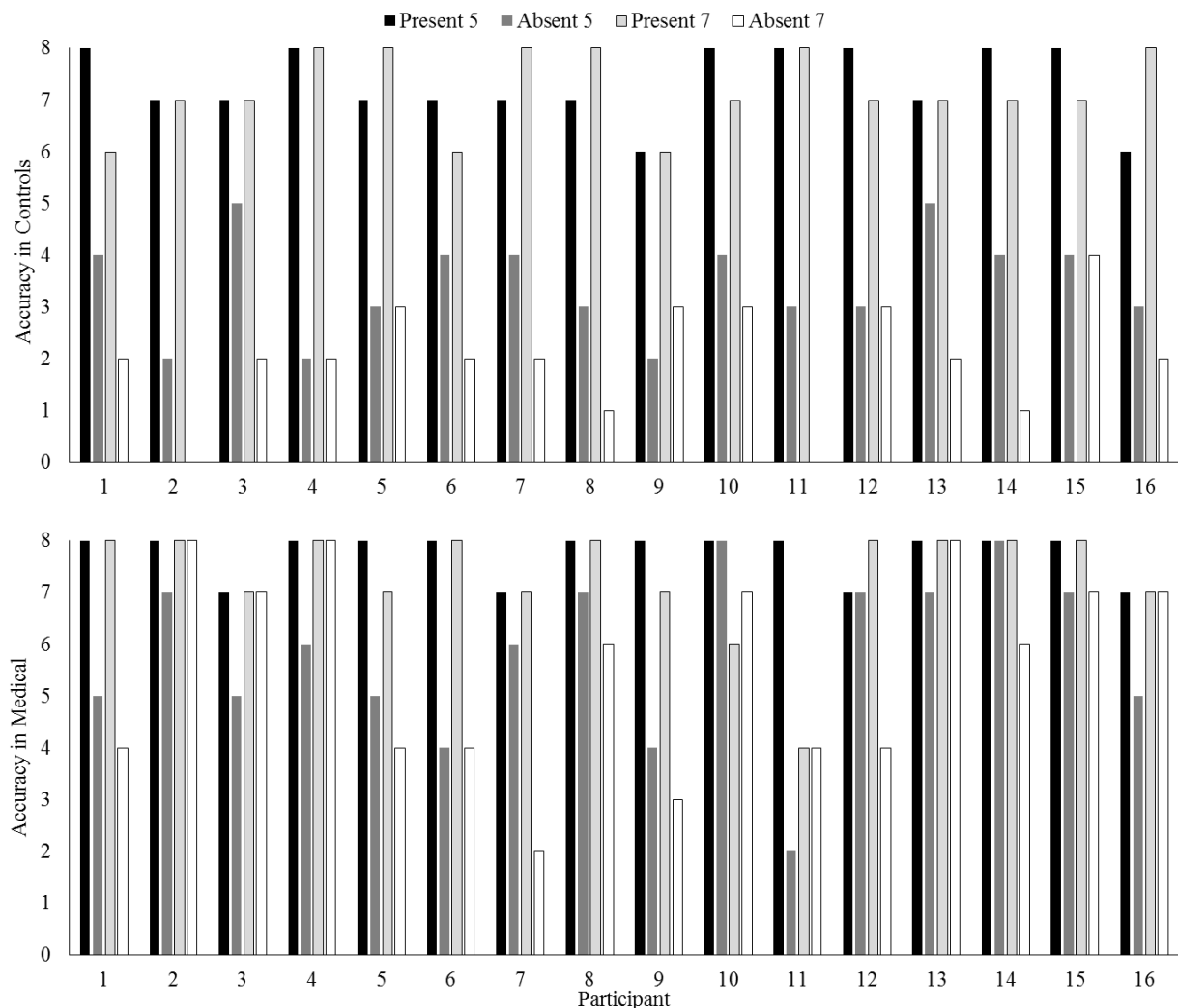
The data for criterion for medical professionals on the seven letter condition were non-normal as determined by a Saphiro Wilk test ( $p = .012$ ) and failed to normalise through logarithmic transformations. Therefore in order to assess the differences in target identification discriminability and bias between groups for the five and seven letter divided attention conditions a mixture of within and between parametric and non-parametric measures were used where appropriate.

The same breakdown analyses that were used in Study 1B were conducted for the types of errors made when participants incorrectly selected a distractor images. Once again these errors were separated by group, target present and target absent trials and by packaging

type.

## Results and Discussion

### Overall Accuracy



*Figure 4.2.* The number of trials (of eight) on which participants made correct target present and absent judgements in control (top panel) and medical (bottom panel) participants for the five and seven letter divided attention task. Black bars and dark grey bars represent the accuracy on target present trials under the five and seven workload conditions respectively. Light grey and white bars with the black borders represent the target absent trials under the five and seven workload conditions respectively.

Figure 4.2 presents a comparison of the overall accuracy on the target identification task for the target present and absent trials under the five and seven divided attention conditions for controls and medical participants. Control participants were more accurate on target present compared to target absent trials for both the five letter (black bars higher than

dark grey bars) and seven letter conditions (light grey bars higher than white bars). The main effect of divided attention is evident in the target absent five letter condition compared to the target absent seven letter condition in control participants (dark grey bars higher than white bars). However, in medical participants there was no consistent difference between judgements on the target present and absent trials for either the five or seven letter conditions.

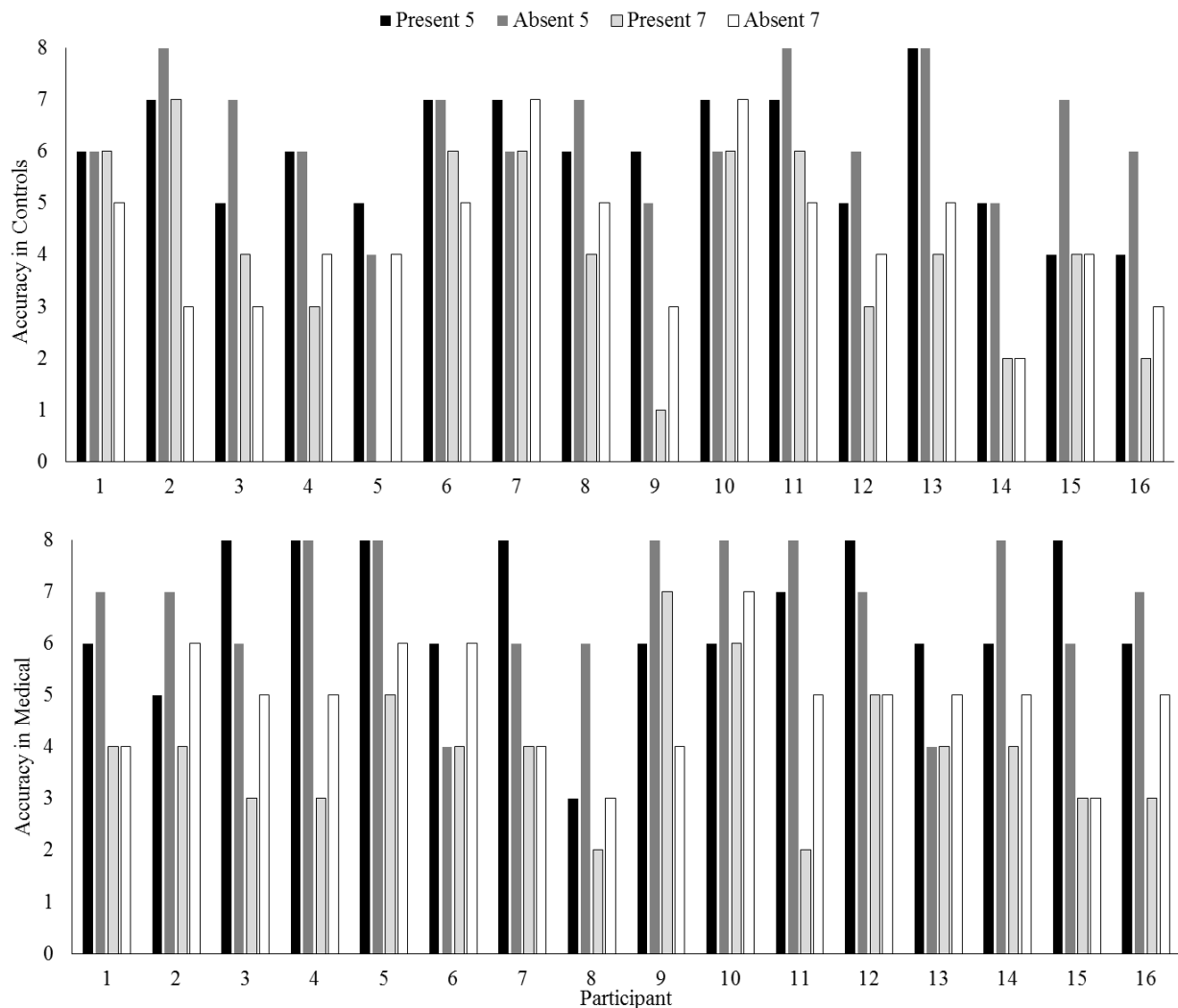


Figure 4.3. The number of trials (of eight) on which control (top panel) and medical (bottom panel) participants responded correctly in the divided attention task on the target present and absent trials for the five and seven letter divided attention task. Black bars and dark grey bars represent the accuracy on target present trials under the five and seven workload conditions respectively. Light grey and white bars with the black borders represent the target absent trials under the five and seven workload conditions respectively.

Figure 4.3 presents a comparison of the accuracy on the divided attention task for the present and absent trials from the five and seven letter conditions for controls and medical participants. Both control and medical participants recalled more letters overall in the five

compared to the seven letter condition regardless of whether or not the target was present or absent in the array.

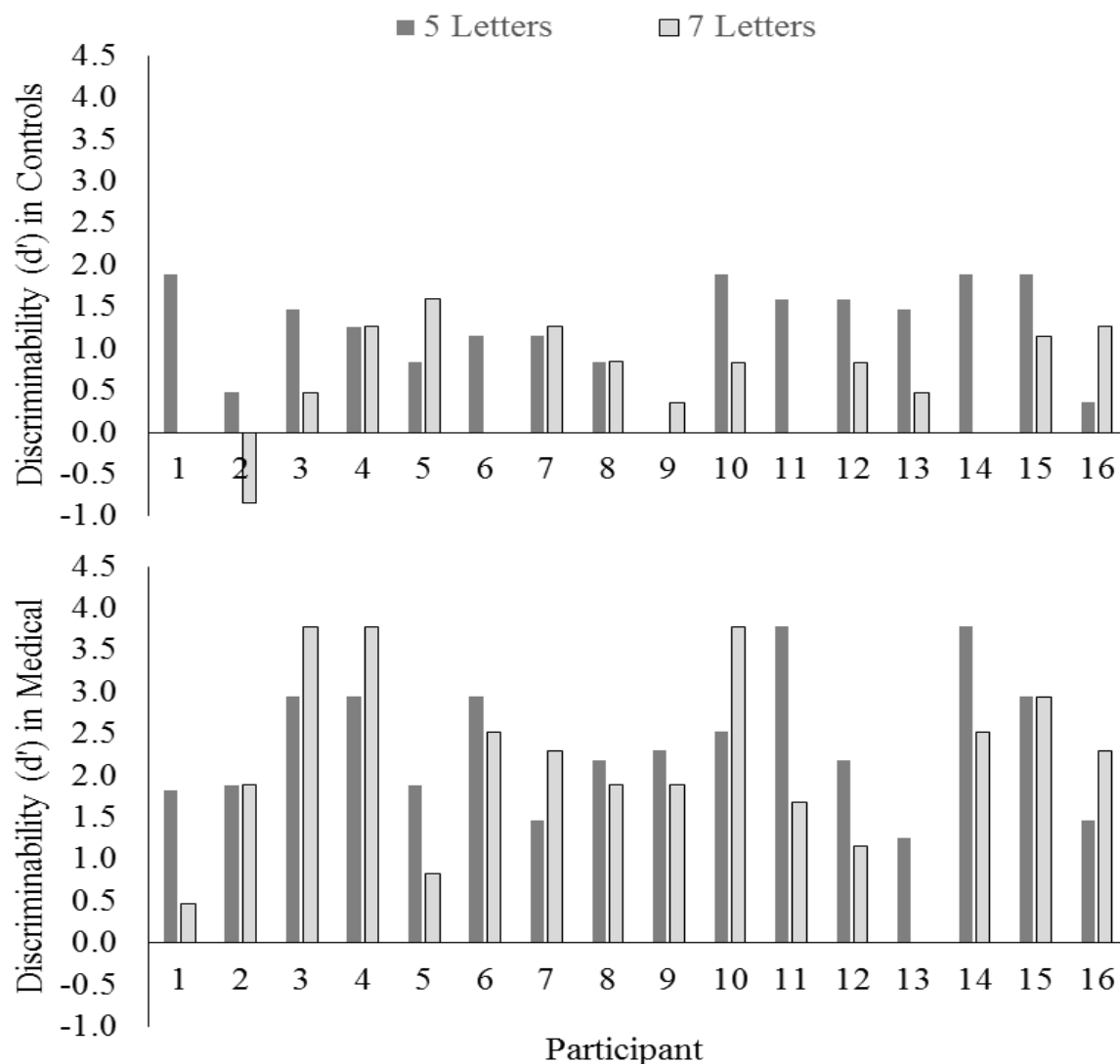
To assess the difference in accuracy of control participants in correctly reporting letters presented in the divided-attention task across the four conditions a two-way repeated measures ANOVA was conducted between target condition (present, absent) and letter condition (five, seven). There was a non-significant main effect of target condition,  $F(1, 15) = 3.29, p = .090$ . There was a significant main effect of letter condition  $F(1, 15) = 54.86, p < .001, \eta_p^2 = .785$ . There was no significant interaction between the target and letter conditions  $F(1, 15) = 0.040, p = .844$ . These results indicated that the only condition that resulted in a difference in the letter accuracy was the number of letters presented in the divided attention tasks with significantly more letters recalled in the five compared to seven letter conditions.

To date there is currently no non-parametric equivalent of a two-way repeated measures ANOVA so therefore a series of Wilcoxon Signed Rank tests were conducted to compare the difference between the conditions of target (present, absent) and letter (5, 7) on the accuracy in the divided attention task for medical professionals. Bonferroni corrections were applied resulting in an alpha level of  $p < .017$ . The only non-significant results were comparisons for whether the target was present or absent for both the five-letter,  $Z = 0.32, p = .746$ , and seven-letter conditions,  $Z = 2.19, p = .028$ . Therefore, as for control participants, there was no significant effect of whether the target was present on accuracy. All other comparisons were significant. Specifically, the target present five letter ( $Mdn = 6$ ) condition was significantly different to the target present seven letter ( $Mdn = 4$ ) condition,  $Z = 3.31, p = .001, r = 0.59$ . The target absent five letter ( $Mdn = 7$ ) condition was significantly different to the target absent seven letter ( $Mdn = 5$ ) condition,  $Z = 3.06, p = .002, r = 0.54$ . Together these results indicate that medical participants recalled more letters in the five compared to seven letter condition regardless of whether or not the target was present or absent.

In Figure 4.3, there is not a convincing difference visible between the overall recall of letters between the control and medical participants on any of the conditions. Consistent with this observation Mann Whitney U tests revealed there were no significant differences between groups for the target present five-letter condition,  $U = 90.50, p = .145$ , or the target absent five-letter condition,  $U = 100.00, p = .274$ . Independent samples t-tests revealed there were no significant differences between the seven-letter target present condition,  $t(30) = 0.10, p = .920$ , or the seven-letter target absent condition,  $t(30) = 1.27, p = .214$ . These results are not consistent with Ghazanfar et al. (2015), who found that novice surgeons were more

accurate on a non-medical divided attention task completed simultaneously with a surgical task when compared to experienced surgeons.

### Signal Detection Theory Analyses



*Figure 4.4.* The discriminability index of control (top panel) and medical participants (bottom panel). Numbers closer to 4.5 indicate near perfect discriminability and numbers closer to 0 represent that discriminability was closer to chance. The dark grey and light grey bars represent the discriminability index under the five-letter and seven-letter divided attention conditions respectively.

Figure 4.4 presents a comparison of the discriminability index for target identification for control and medical participants across the five and seven letter conditions. Medical participants displayed higher overall discriminability than control participants. Nine of the 16 medical participants displayed greater discriminability in the five compared to the seven letter condition. Similarly, nine of the controls also exhibited this pattern. One medical participant

displayed discriminability at chance level for the seven letter condition. Comparatively, chance levels of discrimination could be observed in four control participants with one further participant showing a discriminability of below chance.

A mixed repeated measures ANOVA was conducted between the between factor of group (control, medical) and the within factor number of letters (5, 7). There was a main effect of group,  $F(1, 30) = 32.34, p < .001, \eta_p^2 = .52$ , and number of letters,  $F(1, 30) = 7.63, p = .010, \eta_p^2 = .20$ . There was no significant interaction between group and letter,  $F(1, 30) = 1.11, p = .301, \eta_p^2 = .04$ . Consistent with the observations from Figure 4.4, these results indicate that medical professionals had a significantly higher  $d'$  index than controls, and that the  $d'$  index was significantly higher in the five-letter condition compared to the seven-letter condition. However, increasing the number of letters in the divided attention task from five to seven did not have a larger effect on controls than on medical participants.

Similar to the results for study 1B, these results imply that medical experience increases the ability of an individual to correctly discriminate whether or not a medication is present. Consistent with the findings of Stevens et al. (2013), performance of medical participants decreased as the difficulty of the divided attention task increased. These results were inconsistent with the finding from Ghazanfar et al. (2015) that the ability of experienced surgeons to perform a medical task was not influenced by the divided attention task. However the finding that inexperienced surgeons were influenced by the divided attention task is consistent with the findings for control participants. Finally, Kataoka et al. (2011) found that student nurses were likely to have dispersed attention under dual-task requirements, whereas experienced nurses were not influenced. The findings from control participants support the results of student nurses however medical participants were influenced by the divided attention task in the current study.

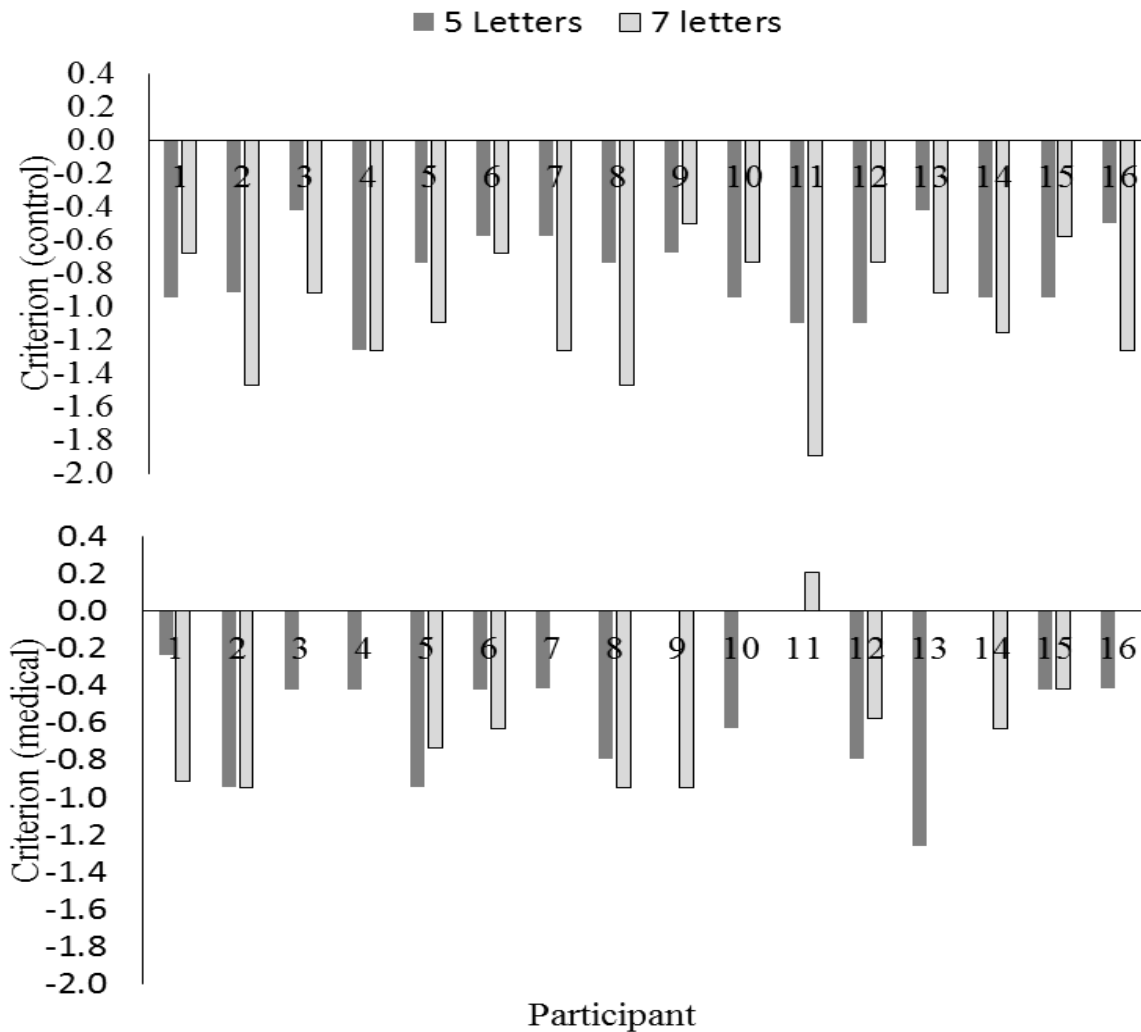


Figure 4.5. The criterion level of control participants (top panel) and medical participants (bottom panel). Negative numbers indicate a criterion level set towards responding that the target is present, a zero indicates that participants showed no bias, and positive numbers indicate that the criterion level was set towards responding that the target was absent. The dark grey and light grey bars represent the criterion level under the five-letter and seven-letter divided attention conditions respectively.

Figure 4.5 presents a comparison of the criterion level for control and medical participants with bars closer to the x-axis indicating less bias. Control participants exhibited more overall bias than medical professionals and were therefore more likely to say that the target was present. Bias was more pronounced in the seven compared to five letter condition for ten of the 16 control participants. The number of letters in the divided attention task did not affect medical participants' level of biases.

A paired samples t-test was conducted between the five ( $M = -0.80$ ,  $SD = 0.26$ ) and seven ( $M = -1.04$ ,  $SD = 0.39$ ) letter conditions for control participants. A significant result

was found,  $t(15) = 2.23$ ,  $p = .041$ ,  $d = 0.72$ , indicating that control participants displayed smaller (more liberal) criterion levels for the seven compared to five letter condition. Consistent with the pattern observed in Figure 4.4, this result demonstrates that control participants were more likely to say that the target was present in trials that had the seven-letter divided attention condition.

A Wilcoxon Signed-Rank test was conducted between the ranks for the criterion levels of the five-letter ( $Mdn = -0.42$ ) and seven-letter ( $Mdn = -0.50$ ) divided attention conditions in medical professionals. Consistent with the patterns observed in Figure 4.4, a non-significant result was found,  $Z = .85$ ,  $p = .396$ , indicating that there was no difference in the level of bias displayed in medical professionals when under the five-letter and seven-letter divided attention conditions.

Mann Whitney U tests were conducted to compare the difference in criterion level between groups for the five,  $U = 68.50$ ,  $p = .024$ , and seven,  $U = 41.50$ ,  $p = .001$ , letter conditions. Consistent with the pattern observed in Figure 4.4, medical participants displayed less bias than controls on both the five-letter and seven-letter divided attention conditions. This result is consistent to the results of Study 1B which indicates that medical participants respond differently under divided attention conditions.

These results indicate that divided-attention in a medical environment does not lead to changes in the bias of medical professionals but may influence inexperienced individuals. Whilst neither Kataoka et al. (2011) nor Ghazanfar et al. (2015) investigated bias, these results are consistent with the findings of their studies. Both studies found that novice or inexperienced individuals were more disrupted by divided attention than experienced individuals. The fact that control participants displayed a greater shift in criterion in the seven-letter compared to five-letter condition indicates that divided attention increases bias and decreases task performance.

### **Breakdown Analysis of Error**

**Target present trials.** Once again, there were two main types of errors that could be made on target present trials. One possible error was to incorrectly indicate that the target was absent (i.e. a miss). The other possible error was to correctly indicate that the target was present but then fail to select the target from the array selecting a distractor instead. Control participants made 72 errors on target present trials, making incorrect judgements about either whether the target was present, or where it was located in the array. Participants responded that the target was absent from the array for 30.56% of errors, and selected an incorrect distractor on 69.44% of trials. Specifically, participants selected the most similar distractor on



43.06% of errors, the second most similar distractor on 18.06% of errors and the least similar distractor on 8.33% of errors. The high rate of errors made where participants selected a distractor instead of responding that the target was absent reflects the bias seen in Figure 4.5 whereby participants tended to respond that the target was present.

Table 4.1

*Break down of the 50 times control participants incorrectly selected a distractor on target present trials*

Change	error	total	%	ampoule			bottle		
				error	total	%	error	total	%
D	7	24	29.17%	1	8	12.50%	6	16	37.50%
DT	4	16	25.00%	2	8	25.00%	2	8	25.00%
NTO	1	8	12.50%	0	0	0.00%	1	8	12.50%
N	15	168	8.93%	8	80	10.00%	7	88	7.95%
NO	7	104	6.73%	4	48	8.33%	3	56	5.36%
ND	9	144	6.25%	8	96	8.33%	1	48	2.08%
DO	1	16	6.25%	0	0	0.00%	1	16	6.25%
NT	1	24	4.17%	0	0	0.00%	1	24	4.17%
NDTO	5	240	2.08%	2	120	1.67%	3	120	2.50%
NDO	0	0	0.00%	0	0	0.00%	0	0	0.00%
NDT	0	24	0.00%	0	24	0.00%	0	0	0.00%

*Note.* Change column represents the type and combination of ways that the target differed from the distractor images, N = Name, D = Dose, T = the top of the medication Band for ampoules or Cap for bottles, and O = Other. For example, if Dose was the only feature changed (D) then Name, Top, and Other features of the distractor selected were identical to the target. Error column represents the total number of times all participants selected a distractor with the change. Total column represents the total opportunities all participants could have selected a distractor with the change. % represents the total percentage of opportunities where error was made.

Table 4.1 presents a breakdown of the types of errors made when control participants incorrectly selected a distractor medication on target present trials. The most common type of errors were made when the distractor varied on the dose or the dose and top of the medication. This pattern of errors is consistent with the eye data from Study 1B whereby

control participants fixated for longer on the Name and Other AOIs compared to the Dose and Cap/Band AOIs.

Medical participants made a total of 30 errors on target present trials. Participants responded that the target was absent for 36.67% of the total errors. Participant selected the most similar distractor for 46.67% of total errors, the second most similar distractor for 10% of errors and the least similar for 6.67% of errors.

Table 4.2

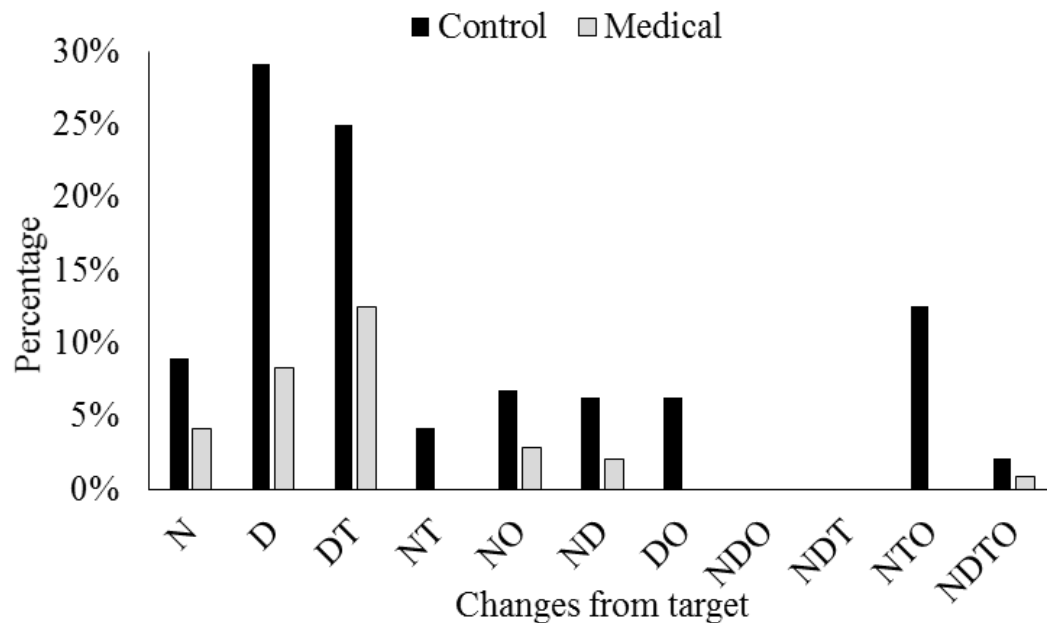
*Break down of the 19 times medical participants incorrectly selected a distractor on target present trials*

Change	ampoule			bottle		
	error	total	%	error	total	%
DT	2	16	12.50%	1	8	12.50%
D	2	24	8.33%	0	8	0.00%
N	7	168	4.17%	2	80	2.50%
NO	3	104	2.88%	1	48	2.08%
ND	3	144	2.08%	1	96	1.04%
NDTO	2	240	0.83%	2	120	1.67%
NT	0	24	0.00%	0	0	0.00%
DO	0	16	0.00%	0	0	0.00%
NDO	0	0	0.00%	0	0	0.00%
NDT	0	24	0.00%	0	24	0.00%
NTO	0	8	0.00%	0	0	0.00%

*Note.* Change column represents the type and combination of ways that the target differed from the distractor images, N = Name, D = Dose, T = the top of the medication Band for ampoules or Cap for bottles, and O = Other. For example, if Dose was the only feature changed (D) then Name, Top, and Other features of the distractor selected were identical to the target. Error column represents the total number of times all participants selected a distractor with the change. Total column represents the total opportunities all participants could have selected a distractor with the change. % represents the total percentage of opportunities where error was made.

Table 4.2 presents a breakdown of the types of errors made when medical participants incorrectly selected a distractor medication on target present trials. Similar to controls the

highest rates of errors were made on distractors where the dose or the dose and top of the medication were the only changes from the target. This pattern is consistent with the eye data from Study 1A whereby medical participants looked significantly longer and more frequently at the Name and Other compared to the Dose and Cap/Band AOIs.



*Figure 4.6.* A bar graph of the percent of total opportunity when errors were made on target present trials for control (black bars) and medical (light grey bars) participants across all possible error types

Figure 4.6 presents a comparison of the percentage of distractors based on the type of changes made chosen by control and medical participants. Control participants made more errors overall in comparison to medical participants. Whilst more errors were made by control participants when only the dose was changed, more errors were made by medical participants when both the dose and top of medication was changed. However, medical participants made fewer errors than controls for both the distractors that were different only in dose and in both dose and top. These findings suggest that, consistent with the findings of Study 1A, medical professionals are more likely to notice the dose of the medication and changes to the name and other properties of the images are more likely to be noticed than changes to the dose or top of the medication.

**Target absent trials.** Control participants made 168 errors on target absent trials (i.e. false alarms). Participants selected the most similar distractor on 73.81% of errors, the second most similar distractor on 17.26% of errors, the third most similar distractor on 4.17% of errors, and the least similar distractor on 4.76% of errors.

Table 4.3

*Break down of the 168 times control participants incorrectly selected a distractor on target absent trials*

Change	ampoule			bottle		
	error	total	%	error	total	%
D	99	160	61.88%	51	80	63.75%
DT	10	32	31.25%	5	16	31.25%
DO	7	24	29.17%	0	0	0.00%
N	29	168	17.26%	6	72	8.33%
NT	4	24	16.67%	4	16	25.00%
NO	9	224	4.02%	8	136	5.88%
ND	4	104	3.85%	1	56	1.79%
NDTO	6	240	2.50%	4	120	3.33%
NDO	0	8	0.00%	0	0	0.00%
NDT	0	32	0.00%	0	16	0.00%
NTO	0	8	0.00%	0	0	0.00%

*Note.* Change column represents the type and combination of ways that the target differed from the distractor images, N = Name, D = Dose, T = the top of the medication Band for ampoules or Cap for bottles, and O = Other. Error column represents the total number of times all participants selected a distractor with the change. Total column represents the total opportunities all participants could have selected a distractor with the change. % represents the total percentage of opportunities where error was made.

Table 4.3 presents a breakdown of errors made when control participants incorrectly selected a distractor on target absent trials. The largest numbers of errors were made on distractors that had the dose, dose and top, or dose and other information changed. Where changes were made across both ampoules and bottle images the rates of error were similar for each packaging type. In comparison changes to the name of the medication were associated with lower levels of error. These results are consistent with the findings from Study 1A that control participants looked more often at the name of the medication than the dose or top of the medication. Error rates were not consistent with the finding that there were longer and more frequent fixations on the Other AOI in comparison to the dose and top of the medication. In Study 1A, it was found that control participants fixated more on the Other

AOI in comparison to the Dose, Name and Cap/Band AOIs. In Study 1B the error rate on distractors with changes to dose and other was 8.33%. A possible explanation of this difference is that the viewing of the parts of the image that do not include the name, dose or top of the medication may change when under increased workload in control participants.

Medical participants made 75 errors on target absent trials. Participants selected the most similar distractor on 69.33% of errors, the second most similar distractor on 22.67% of errors, the third most similar distractor on 5.33% of errors, and the least similar distractor on 2.67% of errors.

Table 4.4

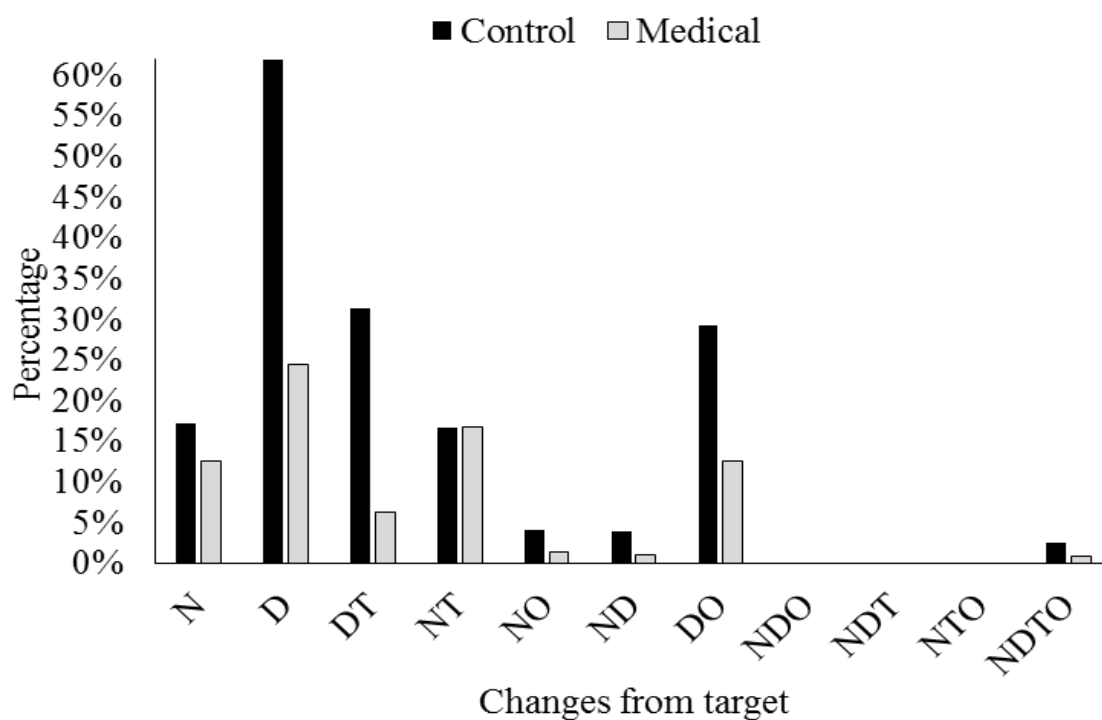
*Break down of the 75 times medical participants incorrectly selected a distractor on target absent trials*

Change	error	total	%	ampoule			bottle		
				error	total	%	error	total	%
D	39	160	24.38%	22	80	27.50%	17	80	21.25%
NT	4	24	16.67%	2	16	12.50%	2	8	25.00%
N	21	168	12.50%	1	72	1.39%	20	96	20.83%
DO	3	24	12.50%	0	0	0.00%	3	24	12.50%
DT	2	32	6.25%	0	16	0.00%	2	16	12.50%
NO	3	224	1.34%	1	136	0.74%	2	88	2.27%
ND	1	104	0.96%	1	56	1.79%	0	48	0.00%
NDTO	2	240	0.83%	1	120	0.83%	1	120	0.83%
NDO	0	8	0.00%	0	0	0.00%	0	8	0.00%
NTO	0	8	0.00%	0	0	0.00%	0	8	0.00%

*Note.* Change column represents the type and combination of ways that the target differed from the distractor images, N = Name, D = Dose, T = the top of the medication Band for ampoules or Cap for bottles, and O = Other. Error column represents the total number of times all participants selected a distractor with the change. Total column represents the total opportunities all participants could have selected a distractor with the change. % represents the total percentage of opportunities where error was made.

Table 4.4 presents a breakdown of errors made when medical participants incorrectly selected a distractor on target absent trials. Similar to the pattern observed in Study 1B the most common type of error in medical participants is to select distractors where only the dose

of the medication differs from the target images. However, inconsistent with the pattern of errors observed in Study 1B, the second most common type of error made was when only the name and top of medication was different from the target. In Study 1B this error rate was only 0.45% and with the addition of divided-attention it has increased to 16.67%. Similarly, errors when only the name was different have increased from 3.57% in study 1B to 12.5% after the addition of divided attention. These results indicate that divided-attention changes the type of errors that occur when selecting a target medication.



4.7. A bar graph of the percent of total opportunity when errors were made on target absent trials for control (black bars) and medical (light grey bars) participants across all possible error types

Figure 4.7 presents a comparison between control and medical participants for the percentage of errors made on distractor images with different changes. The same rates of errors were made for control and medical participants for distractors with name and top of the medication changed from the target. Based on the findings from Study 1A, this result is consistent with the eye data as there were no significant differences between groups in the number or duration of fixations within the Name or Cap/Band AOIs. More errors were made by control participants on distractors where the dose was the only difference to the target. This result is consistent with the results of Study 1A whereby medical participants had longer fixations (and more for ampoules) on the dose of the medication in comparison to control participants. This same pattern can be observed for all changes that include the dose of the

medication in combination with either the top or other properties of the image. Overall these results indicate that medical experience improves the ability of an individual to detect changes based on dose.

### **Conclusion**

Overall these results indicate that participants showed a greater ability to correctly discriminate whether the target was present or absent during the five-letter compared to the seven-letter divided attention task. Overall medical participants compared to controls were better at discriminating whether or not the target was present. There was greater evidence of bias in the five-letter compared to seven-letter divided attention task in controls but no difference was found in bias levels between divided attention load in medical participants. Medical participants displayed less overall bias than control participants in both the five-letter and seven-letter conditions. However, both groups of participants were more likely to adopt a liberal criterion leading to an increase in false alarms. These results indicate that divided attention decreases the discriminability of both control and medical participants, however it only influences the bias of control participants.

## Chapter Five: General Discussion

The primary aims of this thesis were to investigate both the types of error that occur when selecting a medication, and the conditions under which such errors occur. Using a combination of strategies identified from previous literature this thesis used observations from a passive viewing eye tracking study (1A) to inform two studies that utilised a target identification procedure (1B and 1C). Study 1A suggested that the only clear difference between the fixations of participants with medical experience and those without was that medical individuals were more likely to attend to the dose of the medication than controls. Across both groups of participants there were longer and more frequent fixations on the name and other parts of the image than on the dose, cap, or band of the medication. There were some differences between ampoule and bottle medications, specifically, both groups did not fixate regularly on the cap of the bottle medications whereas on ampoules control participants made longer and more frequent fixations on the band of compared to the dose. There were longer and more frequent fixations on the parts of the image not included within the Name, Dose or Cap AOI compared to the name of the medication, whereas there was no difference between fixations on the Name and Other AOIs in ampoule images.

Study 1B suggested that medical experience increases the ability of an individual to determine whether or not a target was in an array. However, medical experience did not make participants any less likely to have a bias towards responding that the target was present. Across all trials the most common type of error made by control and medical participants was incorrectly selecting distractors with only the dose and band different to the target.

Study 1C suggests that there was no difference between the performance of the two groups on the letter task, and that both groups recalled more letters on the five-letter compared to the seven-letter condition. The ability of each group to correctly determine whether or not the target was in the array was impaired by an increase in the load of the divided attention task and medical experience resulted in better discriminability overall. Under divided attention medical participants' displayed less bias than control participants, and their bias was not impaired by an increase in attentional load.

To date the current study is the only known study that assesses where medical professionals look when viewing pre-existing medications, and also includes a signal detection analysis of performance on target identification tasks. Overall this research shows promise in determining which factors influence medication error and provides a method for assessing advances in labelling and packaging that may reduce medication error.



### **The Role of Packaging and Labelling on Medication Error**

The breakdown analyses of error for Study 1B and 1C suggested that participants made more errors on distractors that had only the dose or the both the dose and band/cap changed from the target. This pattern of results is consistent with the eye data from Study 1A whereby both groups of participants looked more at the Name and Other compared to the Dose and Band AOIs. That is, participants did not look at the dose frequently when viewing medications and may have failed to detect that the dose did not match the target when determining whether a drug was present in an array. This error rate is consistent with the review of medication errors by Keers et al. (2013) who determined that wrong dose was one of the common types of medication error.

A potential explanation for the distribution of fixations observed in Study 1A, and the pattern of errors seen across the Study 1B and 1C, is the relative size of the AOI. The Dose and Band/Cap AOIs were smaller than the Name and Other AOIs. Larger AOIs might be expected to attract longer and more frequent fixations than smaller AOIs and it would be more difficult to detect smaller, compared to larger changes, on a label in an array. This interpretation could be investigated by making the dose information a similar size to the name of the medication and determining whether or not there is a reduction in errors on distractors where dose is the only difference to the target. If increasing the size of the dose does not increase fixation time and reduce selection of distractors with changes to the dose, this result would suggest that there is another factor associated with dose that reduces attention. If increasing the dose increases fixations and reduces selection of distraction with changes to the dose, this result would suggest that increasing the size of the dose could help reduce medication error.

Study 1A showed that medical participants fixated more on the dose of the medication than control participants. Therefore, it would be important to use medical professionals to test any intervention that manipulates features of the dose in an attempt to mitigate error.

Changes to the name, top of the medication and/or other information did not result in any consistent difference in error rate across the eight breakdown analyses. The majority of these errors occurred at a similar rate to each other and seemed to make up a base rate of general error. During the experiments targets in one array were also presented as distractors in other arrays. It is possible this base rate of error is because participants were misremembering a target presented in a previous trial. To determine the influence of interference from previous trials future research could manipulate whether or not targets were

presented as distractors in previous trials to see if this alters or reduces the types of errors made when selecting a distractor image.

The Other AOI of a medication contained any part of the image that was not included in the Dose, Name, or Cap/Band of the medication. On many medications this includes things like brands, logos, barcodes, and the actual container of medications (i.e. the glass that contains the medication). In a review of medication errors Berman (2004) reported that many label factors that are contained in this Other AOI are responsible for medication errors. Berman suggested that these factors led to error because they were being used to identify a medication instead of the name and dose which are the dimensions on which selection should be made. In the current study the most frequent error made was on distractors that differ in dose but with the other information the same. This result could imply that, consistent with the suggestion of Berman, participants were making their identifications based on the information included within the Other AOI.

This study did not systematically change names to similar sounding or looking names. Berman (2004) reported that name confusion accounted for 25% of medication errors. Consistently, studies examining look-alike and sound-alike medication names reported that errors increased as similarity in names increased (Lambert, Lin, Chang, & Ghandi, 1999; Lambert, Chang, & Lin, 2001; Lambert, Chang, & Gupta, 2003; Gabriele, 2006). Tall Man lettering has been introduced as an intervention to mitigate errors in medications with similar sounding names however the previous methodologies have had varying success (Zhong et al. 2012). The current methodology could be modified to assess the role of Tall Man lettering to reduce errors in similar sounding and looking names by creating changes in name that include Tall Man lettering. By comparing base rates of error on regularly presented similar sounding and looking names to errors on names with Tall Man lettering this study would provide further understanding as to the role of Tall Man lettering in reducing errors due to name similarity.

Overall, the results of this study suggest that, consistent with suggestions made by Berman (2004), labelling of medications should focus on increasing the size and salience of the name, and particularly, the dose of the medication. By reducing the size of information such as the brand, logo or manufacturer and increasing the size of the name and dose of the medication, the information that is necessary for identification may increase the salience of the dose. These changes may reduce the frequency of medication errors in an applied medical setting. Further, the re-designed labels tested by Dieckmann et al. (2014) and Estock et al. (2015) from the guide for labelling and packaging from the National Patient Safety Agency

(National Patient Safety Agency, 2008) incorporate changes that increase the salience of the dose.

Additionally, Berman suggested increasing the consistency in dose presentations, i.e. presenting doses as 0.2 rather than .2 or 2 rather than 2.0. Future research could use the current methodology to examine the influence of changes to dose size and consistency in dose presentation by systematically altering the size and presentation of the dose to determine whether or not these factors help to decrease error.

### **Signal Detection Theory and Target Identification**

The results showed that there was a high rate of false alarms in both target identification experiments (studies 1B and 1C). Swets (1998) suggests two factors that can influence the criterion for a decision. Firstly, the criterion is affected by the costs associated with each error type (false alarms versus misses) - people are more likely to make false alarms when these are a less costly error type than misses. For example, when checking scans for a serious illness a miss results in failing to detect a tumour which may in turn lead to patient death. It is difficult to determine whether this factor can explain the high rates of false alarms in the current study because there are many considerations that influence the cost and benefits associated with false alarms in medical settings. False alarms are more costly when a very dissimilar medication is given and less costly when a similar medication is given. Misses are more costly when the medication is needed immediately and a miss results in delayed administration. Misses are less costly when the drug is not needed immediately and the medical professional quickly rectifies their error.

In the current study participants were not instructed that either a miss or a false alarm was more costly during the experiment. There was also no measure to determine the perceived cost associated with either type of error. Future studies could assess the involvement of this factor in the rate of false alarms by measuring participant's perceptions of the costs of error after completion of the task.

The second factor that can influence the criterion for decision is that a liberal criterion (which leads to a higher rate of false alarms) is commonly adopted when the prior likelihood of the target being present is higher than it being absent (Swets 1998). In the studies 1B and 1C the target was present 50% of the time therefore the probability of the target being in the array should not have driven the high rate of false alarms. One possible explanation of the high rate of false alarms in medical participants is that in the applied medical setting participants have direct previous experience with a high presentation probability of target

medications. Medications that are frequently used during surgery are regularly stocked and therefore medical professionals are rarely in a setting where the medication is absent from the selection of possible choices. However, this explanation does not explain why medically naïve participants, who have no direct experience with the rate at which target medications are typically present in medical settings, also displayed a high rate of false alarms that did not differ significantly from medical participants.

A second possible explanation that could account for the high rate of false alarms seen in both groups is the influence of pre-existing expectations. Research from Schwark, MacDonald, Sandry and Dolgov (2013) suggest that pre-existing expectations are more likely to drive decisions than actual target probability. In the current study, both groups of participants may have been operating under the expectation that the necessary medication is typically present in a medical setting. This explanation could be tested by replicating the current study and asking participants to estimate the likelihood of the target being present in the array before and after they have completed the task. If estimates for most participants were higher than fifty percent, and estimations that the target would be present were correlated with false alarm rates, this would support this explanation for the high rate of false alarms observed currently.

There are three potential interventions that could reduce bias: feedback, presentation of medication in an array, and task instructions. Firstly, if participants make false alarms because they overestimate the likelihood that the target is present, one way to reduce this issue would be to target the beliefs that govern this bias. Participants in the experiment did not receive feedback on their performance for the target identification and therefore their pre-existing expectations were never challenged. That is, participants were not made aware that when they incorrectly identified the target as present (i.e. made a false alarm) the target was not present in the array. This might have contributed to inflated estimates of target presentation probability. If feedback was introduced then this may reduce the tendency of participants to respond that the target was present.

Whilst the addition of feedback to reduce bias is intuitively sound, research from other tasks involving target identification have produced varying results. Schwark et al. (2013) suggests that even in the presence of feedback participants' existing expectations are more likely to drive judgements than their actual perception that the target was in the array. Across two experiments participants received feedback on their performance on a trial-by-trial basis and it was found that participants increased the use of expectation-based decisions in difficult search tasks. From Schwark et al. it seems apparent that feedback did not alter the

pre-existing expectations of participants. In contrast, literature in face identification provides limited support for the role of feedback to reduce bias in a task that involved a same/different response for face stimuli (Meinhardt, Meinhardt-Injac & Persike, 2014). Responding on their study revealed an overall bias towards responding that the target was different on trials where stimuli were dissimilar. The inclusion of feedback reduced the response bias of participants for dissimilar trials only, however it did not alter the overall accuracy of the participants. In trials where stimuli were similar feedback trended towards decreasing overall performance. From these results Meinhardt et al. concluded that feedback was not useful in improving overall performance on the task.

Secondly, bias could be reduced by presenting medications sequentially rather than simultaneously in an array. Research from eyewitness identification of a suspect has investigated the possibility of reducing false alarms through sequential presentation of the suspects rather than simultaneous presentation (Meissner, Tredoux, Parker & MacLin, 2005). Eye-witness identification is another situation in which people judge whether or not a previously seen stimulus is present in a range of stimuli. Over four experiments Meissner et al. determined that sequential presentation of line-ups lead to a more conservative criterion so that participants were less likely to say that the target was present in the line-up. Upon review of this result Dobolyi and Dodson (2013) and Wixted and Mickes (2014) used signal detection measures to conduct a comparison of accuracy on sequential versus simultaneous line-ups. Dobolyi and Dodson found that, while their analysis revealed that participants were less likely to respond that the target was present in a sequential line-up, they were also less accurate on sequential compared to simultaneous line-ups. Similarly, Wixted and Mickes (2014) found that simultaneous presentation of targets resulted in higher discriminability than sequential presentation. If applied and replicated in a medical setting then sequential presentation of medications could reduce the overall tendency to respond that the target is present, however it would also reduce the accuracy of the task. Therefore, it must be determined whether it is more important to administer the required medication at the risk of selecting an incorrect medication or determine that a necessary medication is absent and therefore not administer any medication.

Thirdly, the final suggestion of an intervention aimed at reducing bias involves the types of instructions used during the task. During the task participants received no instructions about their criterion for guessing that the target was present. Meissner et al. (2005) included a condition in one of their experiments whereby participants were instructed to “only respond to a line-up member if you are 100% confident” (p. 787). This instruction

led to a reduction in the likelihood of an individual responding that the target was present and also led to an increase in the ability of an individual to correctly determine whether or not the target was in the line-up. Research in psychophysics also suggests that the use of inhibitory instructions such as the example above can reduce response bias without influencing discriminability in target identification tasks (Clark, 1966).

Additionally, characteristics of the experimental setting might cause participants to have the expectation that the target is more likely than not to be present in each array. For example, participants were asked to indicate the targets location in the array on each trial regardless of whether or not they responded that the target was present. After responding whether or not the target was present or absent participants were then asked to “select the location of the target”. Although they had to option to respond again that the target was absent this instruction could have lead participants to believe that the target was present. Biased instructions have been shown to increase the amount of response bias in eyewitness target identification (Brewer and Wells, 2006).

Future research could be conducted to assess the use of inhibitory instructions in reducing response bias for medication selection. Instructions such as “only respond if you are 100% sure that the medication is in the array” could be used to determine whether or not response bias decreases and discriminability remains stable. In addition the location selection question could be changed to an unbiased question such as “if the target was present please select its’ location in the array”. If there is a reduction in response bias under conditions with these types of instructions then this technique could be investigated more thoroughly in an applied medical setting such as a simulated operating theatre.

### **Divided Attention and Target Identification**

The results from study 1C demonstrated that the ability of control and medical participants to correctly discriminate whether or not the target was present in the array was influenced by the extent of divided attention. Both groups of participants displayed lower discriminability in the seven-letter, compared to the five-letter divided attention task. The divided attention task influenced the control participants’ ability to correctly determine whether or not the target was present in the array to a greater extent than medical participants. This pattern is consistent to Kataoka et al. (2011) and Ghazanfar et al. (2015) who found that novice participants were more influenced by distraction.

However, for expert participants Kataoka et al. (2011) and Ghazanfar et al. (2015) found that performance on the medical task was not influenced by the divided attention task.

Conversely, the current study found that, consistent with Stevenson et al. (2013), medical professionals displayed a decrease in discriminability with increased attentional load. A possible explanation of this inconsistency is that the divided attention tasks used by Kataoka et al. or Ghazanfar et al, were different to Stevenson et al. and the current study. The divided attention task utilised by Kataoka et al involved listening to newscast with the intent of recalling information while undergoing the medical task. In this task participants were trying to remember related information for later recall, whereas the information in the current study was unrelated. The divided attention task utilised by Ghazanfar et al. involved participants monitoring and responding to changes in an auditory distraction task of increasing difficulty while completing a surgical task. In this task participants made responses as soon as changes were detected and did not need to retain information. The divided attention task utilised by Stevenson et al. involved participants responding to the presence of a red letter from a series of sequentially presented white letters while attending to an auditory medical task. In this task participants made responses to the divided attention task whilst also monitoring and making responses to a simultaneously occurring auditory task. It is possible that the tasks used by the current study and Stevenson et al. required more attentional resources than those of Kataoka et al. and Ghazanfar et al. and thus disrupted the performance of medical participants.

One further inconsistency between the current study and the findings of Ghazanfar et al. (2015) is seen in the performance on the divided attention task. Ghazanfar et al. found that novices were more accurate than expert participants on the divided attention task. From this result they suggested that experts were better at filtering out irrelevant stimuli and focussing on the task at hand. That is, medical professionals made a task-accuracy trade-off where they maintained their performance on the medical task by prioritising it over performance on the divided attention task. The current study found no difference between groups on the divided attention task. One possible explanation for this result was that medical participants did not attain their high accuracy on the drug identification task by making a task-accuracy trade-off and “filtering out” the divided attention task. In spite of instructions that stressed the equal importance of both tasks, anecdotally, many medical participants reported focusing on the medication selection task at the expense of the divided attention task. However, this is difficult to evaluate because we do not know how well either group of participants would have performed on the letter task when they were not required to also perform the drug identification task (i.e. in the absence of any potential task-accuracy trade-off). To test this theory it is suggested that future research include a condition whereby participants complete the divided attention task in isolation. By including a measure of base rate performance on

the divided attention task it would be possible to see if either group made a task accuracy trade-off when the task was combined with target identification.

A potential criticism of the divided attention tasks used by the current study and previous research is that they can be dismissed without causing negative consequences, perhaps making them dissimilar to tasks that doctors must perform in combination with medication selection in applied settings. In an objective analysis of the tasks and levels of workload for an anaesthetist during surgery Weigner et al. (1994) listed a variety of essential tasks such as observation of the patient, airway, breathing, surgical field and monitors. Investigating the role of distraction by using tasks that could be dismissed does not assess the influence of crucial tasks that require attention during medication selection. Future research could investigate the inclusion of medical divided attention tasks that simulate tasks that are essential to attend to during surgery. One such task could include the addition of a patient monitor that requires participants to recognise and/or respond to changes of patient physiological parameters throughout the experiment.

## **Conclusion**

Overall, this thesis demonstrated that there were differences in how medical professionals viewed and identified medications in comparison to controls. Results suggest that medical experience leads to an increase in fixations on the dose of the medication and an increased ability to discriminate whether or not a target medication was present in a selection of medications. Both groups of participants displayed a response bias towards responding that the target was present in the array, which produced an increase of false alarms. A possible intervention to reduce false alarms could assess the effectiveness of inhibitory instructions before target identification. An increase in the difficulty of the divided attention task was shown to decrease discriminability. Finally, while the biases of medical participants were not influenced by divided attention, control participants displayed an increase in bias under the seven-letter, compared to five-letter condition. The present research provides a new approach to determining the influence of packaging on medical error. The contribution of a signal detection theory analysis revealed that the majority of medical participants adopted a liberal criterion for determining whether or not a target is present in an array and that divided attention influences both the bias and discriminability of judgements in medical professionals. Further research is required to replicate the findings of the current study and to investigate interventions that could be applied in a medical setting to reduce both the rate of incorrect selection of a medication and the influence of distraction on medication error.



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## Appendix A: Participant Information

Table 1. Presents the ID, job title and years of clinical experience reported by medical participants.

*Medical participant information*

ID	Job title	Experience
1	Nurse	17
2	Dr Anaesthesia	4
3	Doctor Anaesthesia	37
4	Dr Anaesthesia trainee/RMO	6
5	Doctor Anaesthesia SMO	15
6	Nurse	12
7	Doctor Anaesthesia	6
8	Nurse	6
9	Doctor Anaesthesia	35
10	Doctor Anaesthesia	8
11	Doctor Anaesthesia SMO	24
12	Doctor Anaesthesia SMO	10
13	Technician	-
14	Doctor Anaesthesia	17
15	Doctor Anaesthesia	8
16	Dr Anaesthesia trainee/RMO	9

*Note.* ID refers to the participant number used in all graphs. SMO = Senior Medical Officer, RMO = Resident Medical Officer. Experience refers to years of clinical experience as reported in the survey given to medical participants (refer to Appendix A for full survey). Participant 13 did not disclose their years of clinical experience.

## Appendix B: Survey Given to Participants

Visual recognition of medication labels and packaging questionnaire**Please circle the item that applies to you**

I am:

- A nurse
- A midwife
- A nurse practitioner
- A pharmacist
- Doctor Anaesthesia    Intensive Care    Emergency Medicine
- Other Specialty:  
Trainee/RMO   Vocational Specialist/SMO   Other:
- None of the above

**Please indicate your agreement or disagreement to the following statements**

- 1) I am required to select and identify medications and place them in allocated storage places (e.g. drug trolley drawers, dispensing machines etc.).      Yes    No
- 2) I am required to select and identify medications that are administered to patients.      Yes    No
- 3) I am aware that I have accidentally selected an unintended drug on at least one occasion.      Yes    No  
Unsure
- 4) I have never, to my knowledge, accidentally selected an unintended medication.      Yes    No  
Unsure
- 5) Medication presentation and labelling allows medications to be correctly identified  
Strongly Agree    Agree    Neither Agree nor Disagree    Disagree    Strongly disagree
- 6) I find it difficult to correctly identify medications:  
Strongly Agree    Agree    Neither Agree nor Disagree    Disagree    Strongly disagree

**Please enter the following details**

Years of Clinical Practice

Gender

Age

Subject ID code: \_\_\_\_\_

Appendix C: Enlarged Graphs of Total Fixation Time (ms) for Ampoule Images

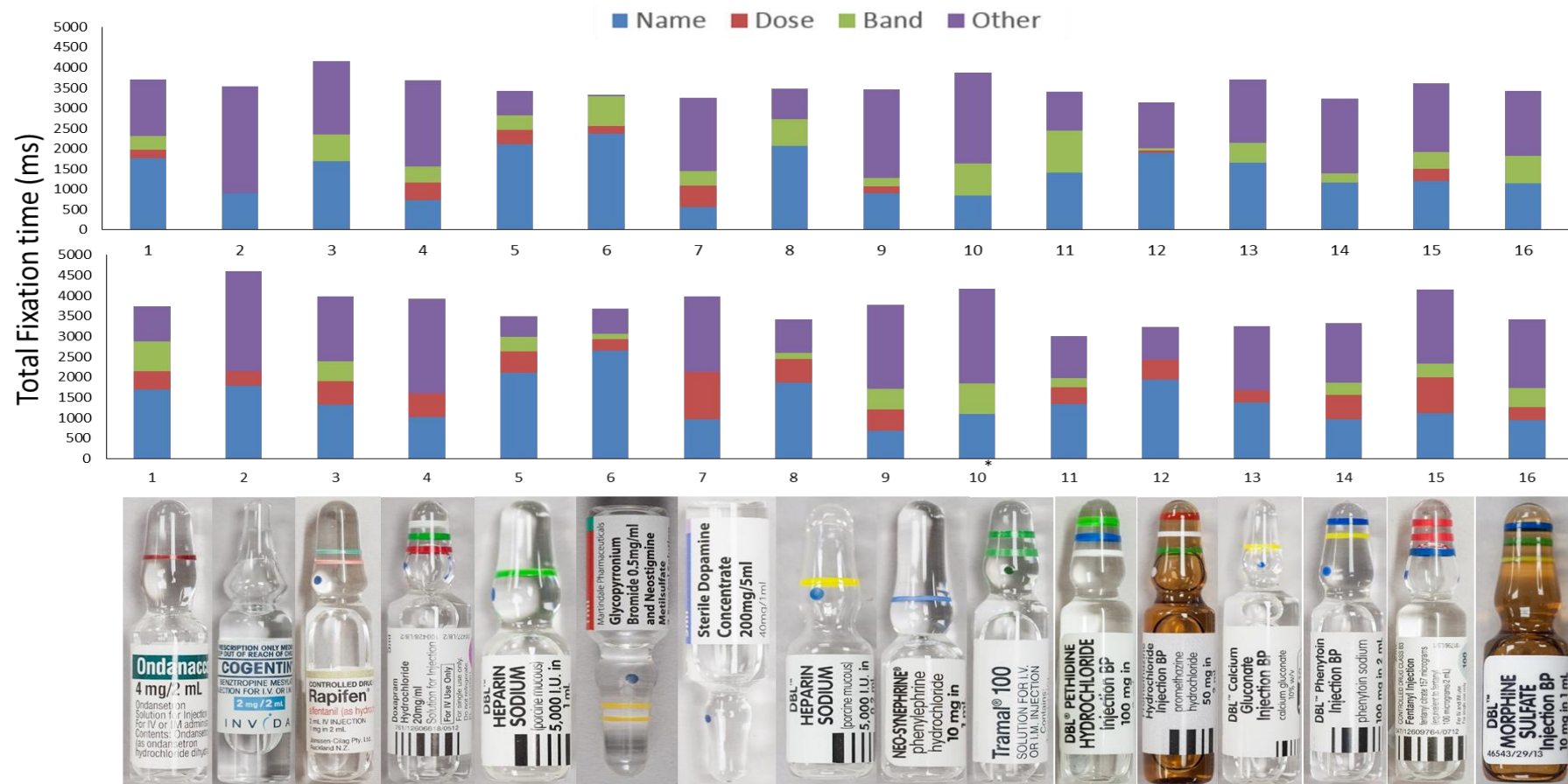


Figure 1. The median total time in milliseconds fixating on ampoule images, by participant, for each of the four AOIs (colours in stacked bar graphs) for control (top panel) and medical (bottom panel) participants.



Appendix D: Enlarged Graphs of Total Fixation Time (ms) for Bottle Images

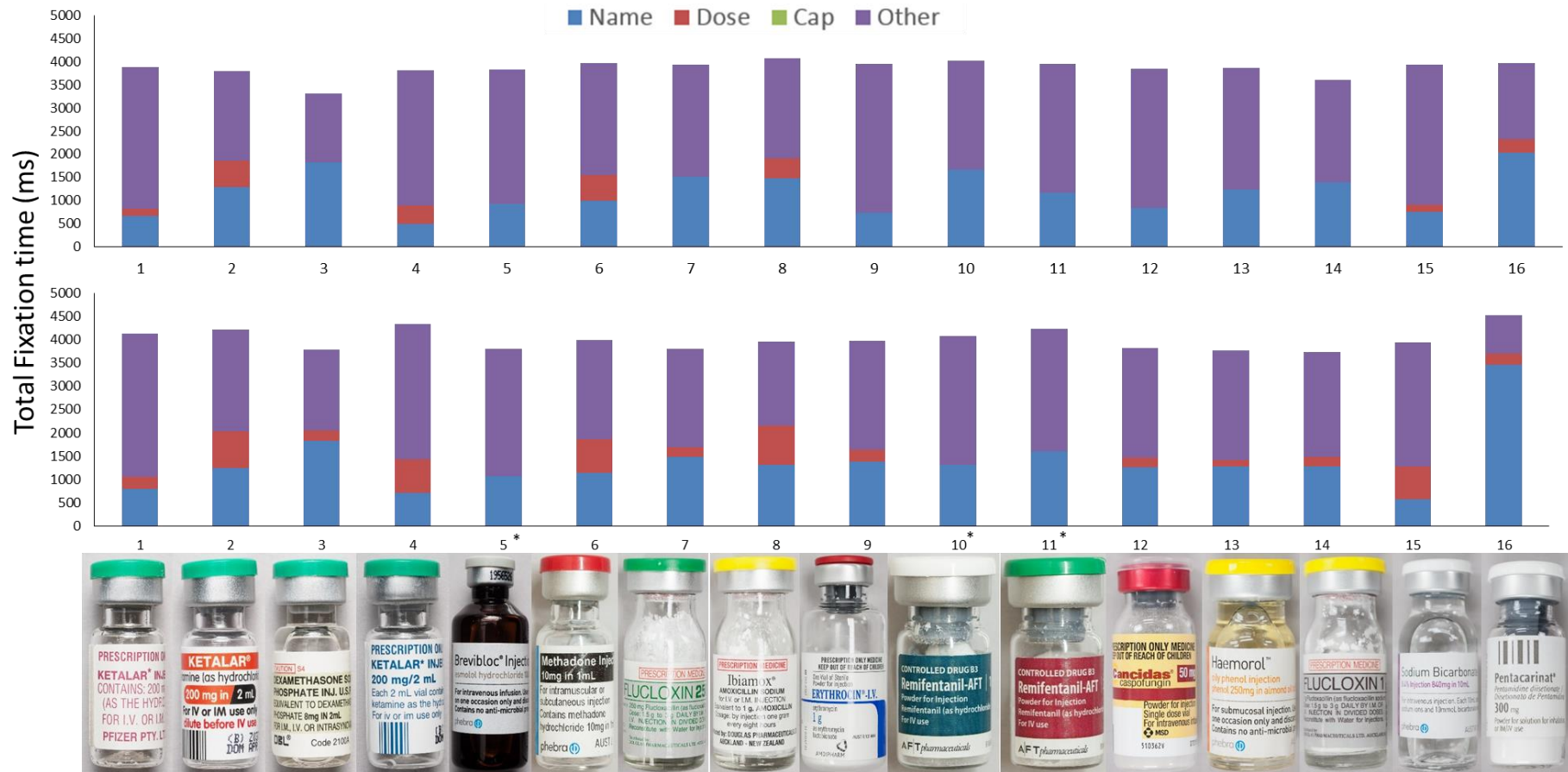


Figure 1. The median total time in milliseconds fixating on bottle images, by participant, for each of the four AOIs (colours in stacked bar graphs) for control (top panel) and medical (bottom panel) participants.

Appendix E: Enlarged Graph of Total Number of Fixations for Ampoule Images

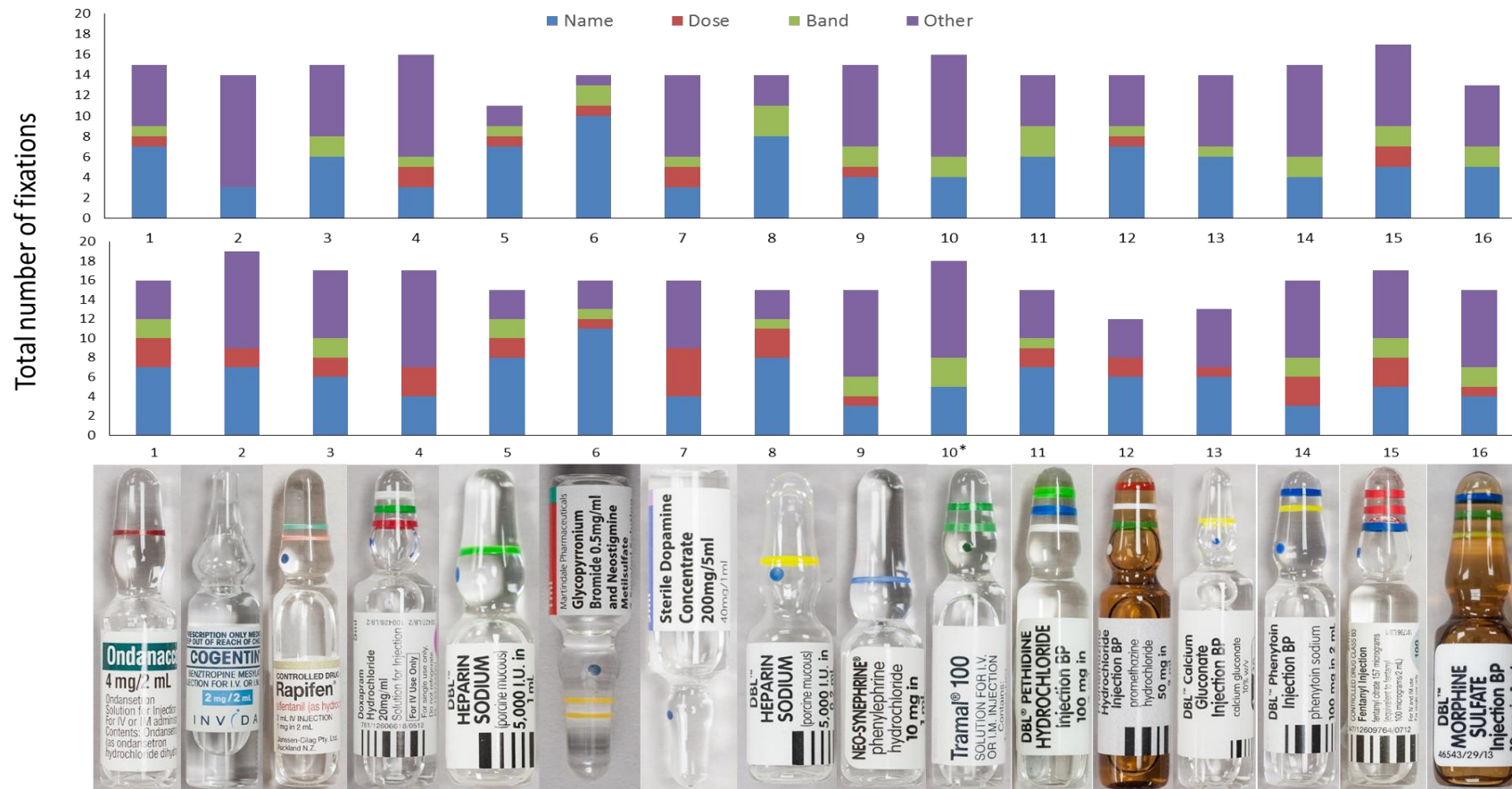


Figure 1. The median total number of fixations on ampoule images, by participant, for each of the four AOIs (colours in stacked bar graphs) for control (top panel) and medical (bottom panel) participants.

Appendix F: Enlarged Graph of Total Number of Fixations for Bottle Images

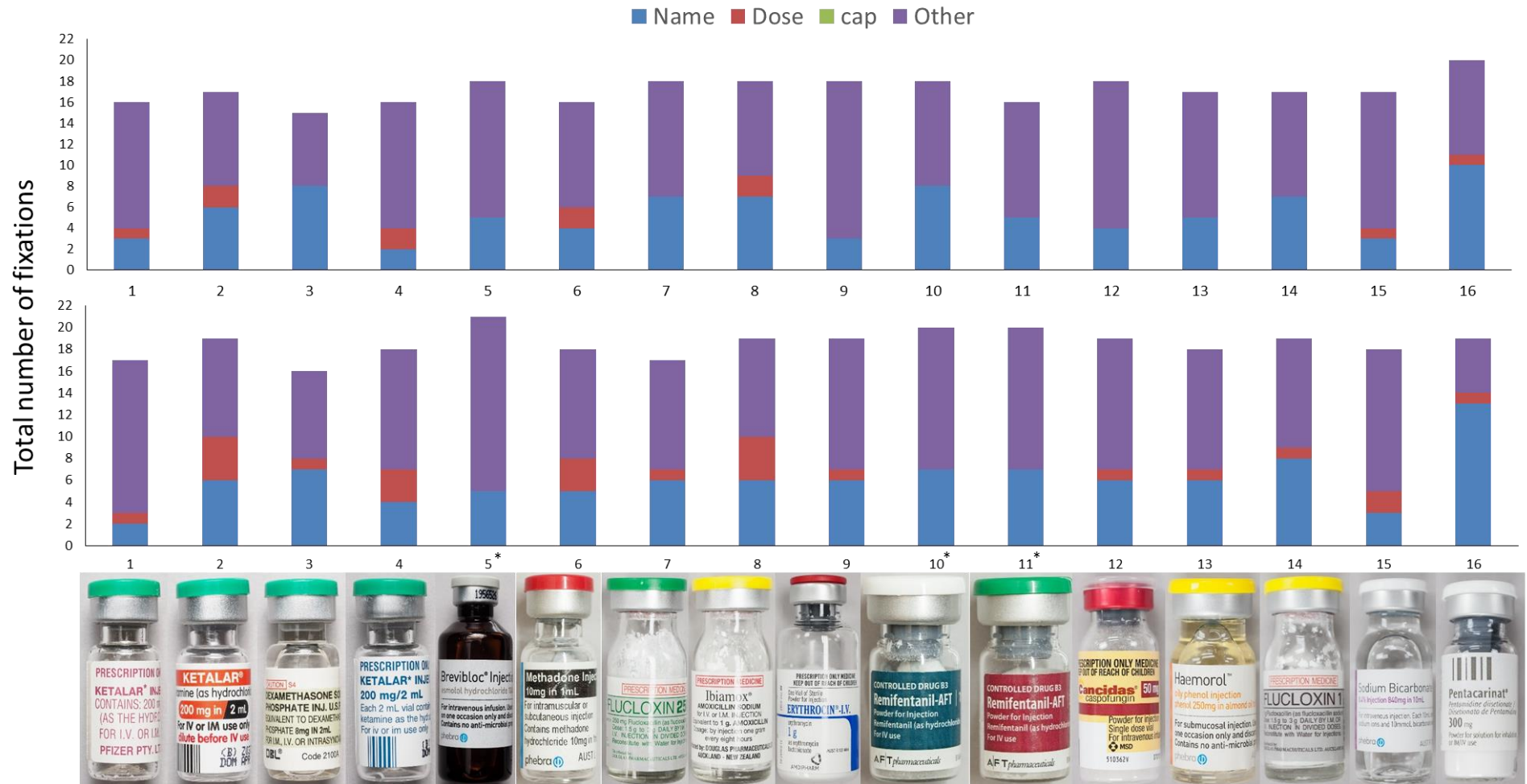
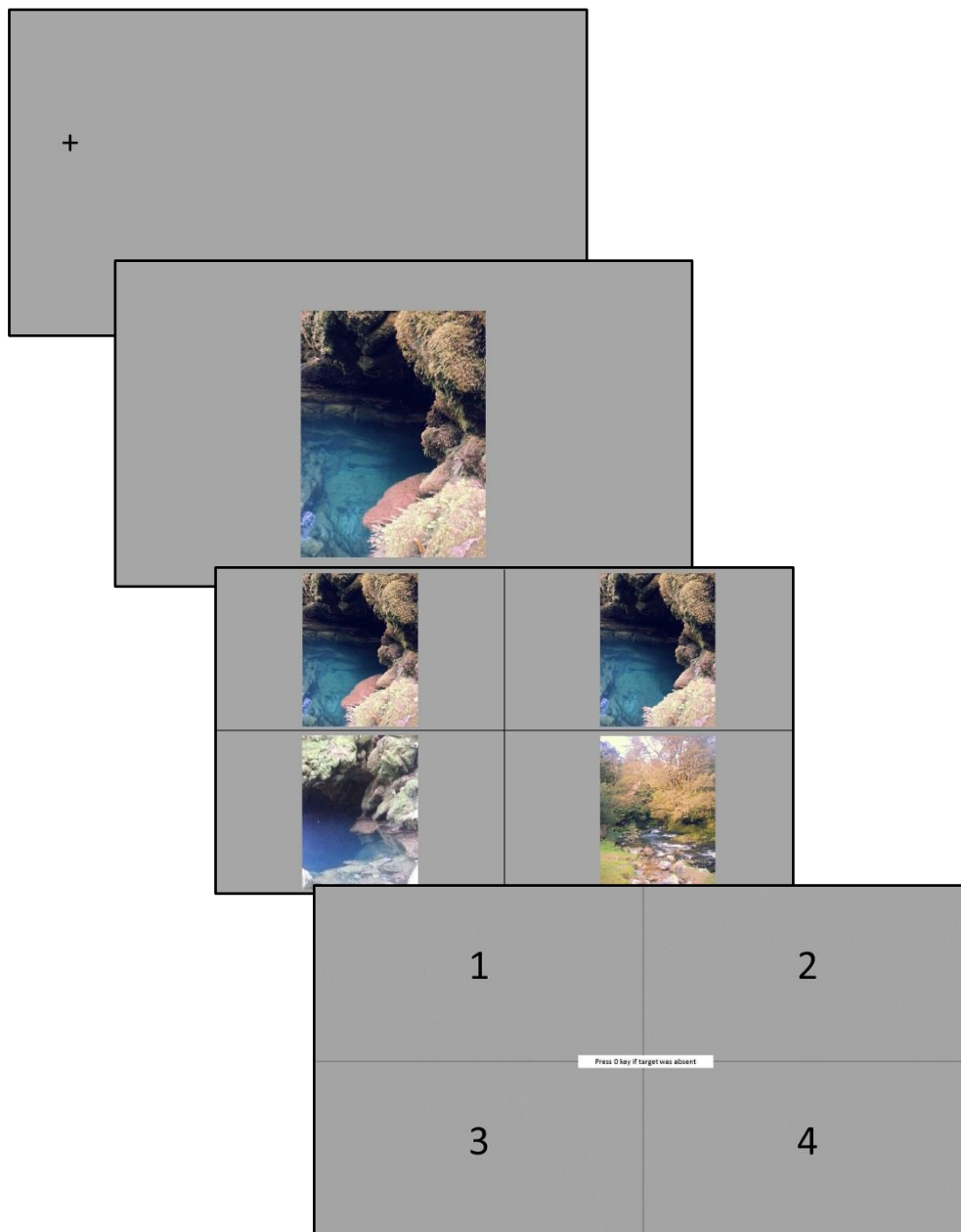
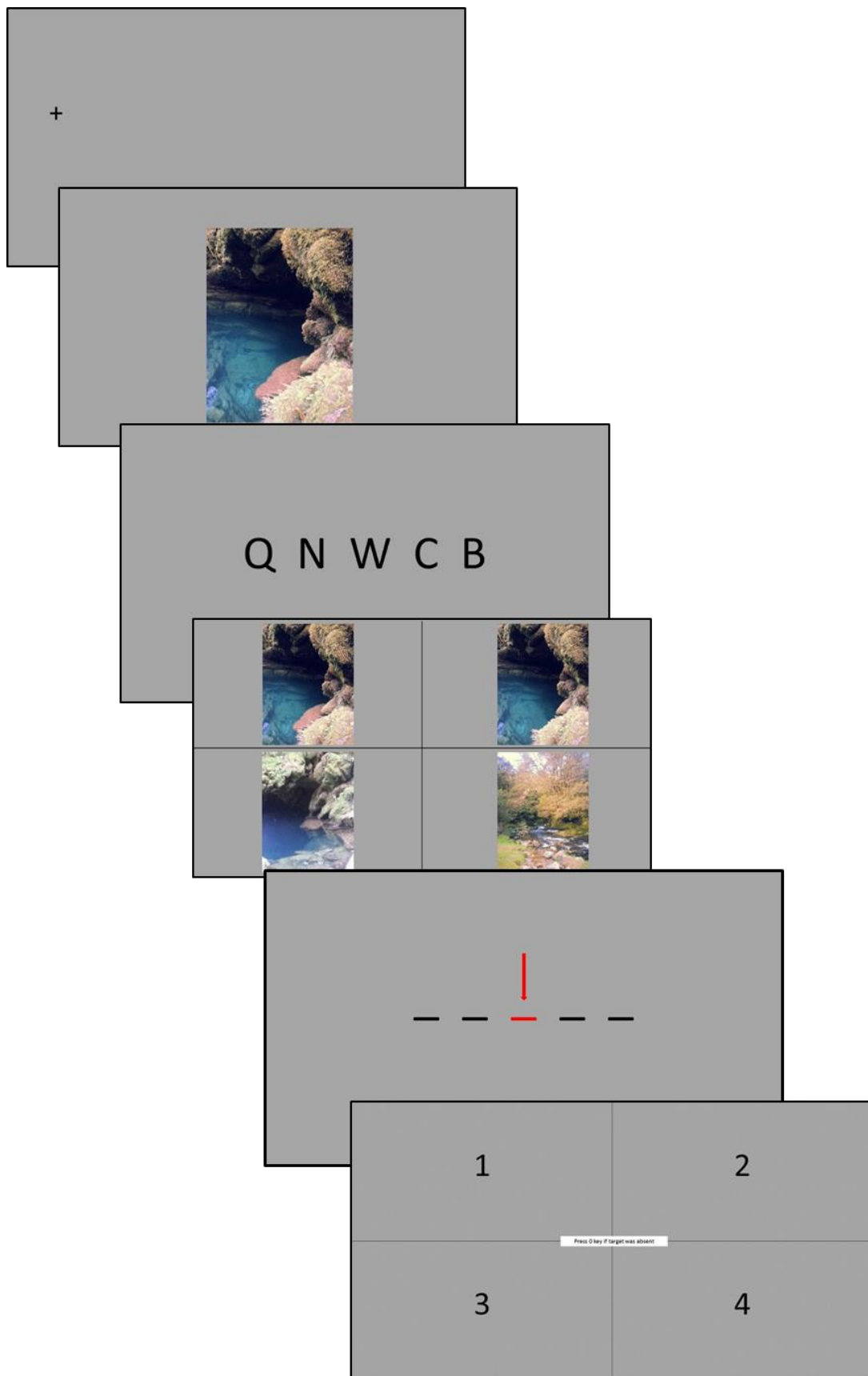


Figure 1. The median total number of fixations on bottle images, by participant, for each of the four AOIs (colours in stacked bar graphs) for control (top panel) and medical (bottom panel) participants

## Appendix G: Example of a Practice Trial



*Figure 1.* An example of a practice trial for Study 1B. In the last screen participants responded with a zero if they thought the target was absent



*Figure 2.* An example of a practice trial for study 1C. In the last screen participants responded with a zero if they thought the target was absent

## Appendix H: Consent Form for Participants

**Visual recognition of drug labels and packaging**

Carrie Bailey (MSc Student) *carrie.bailey@vuw.ac.nz*

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Dr Anne Macaskill (Research Fellow) *anne.macaskill@vuw.ac.nz* (04) 463 9464

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Dr Natasha Buist (Senior Tutor) *natasha.buist@vuw.ac.nz* (04) 463-6754

**What is the purpose of this research?**

This research will allow us to examine how people identify drugs that are administered to patients.

**Who is conducting the research?**

- We are a team of researchers in the Schools of Psychology and Nursing, Midwifery & Health at Victoria University of Wellington. Dr. Macaskill and Dr. Robinson are supervising this project. This research has been approved by the School of Psychology Human Ethics Committee under delegated authority of Victoria University of Wellington's Human Ethics Committee.

**What is involved if you agree to participate?**

- If you agree to participate in this study, you may be required to complete a short survey where you will respond to items such as "I am required to select and identify medications that are administered to patients". We will then test you for colour blindness. We will show you a series of images on a computer screen. These will be medication vials and boxes and we may ask you to identify them. We anticipate that the survey and tests will take you approximately 60 minutes to complete.
- During the research you are free to withdraw, at any point before the experiment has been completed.
- To thank you for participating, we will give you one movie voucher.

**Privacy and Confidentiality**

- This survey is completely anonymous. Please do not put your name on it anywhere.
- We will keep your survey for 5 years and then destroy it.
- Data without identifying names may be used in other, related studies.
- A copy of data without identifying names will remain in the custody of Dr Anne Macaskill and held in her lab in a secured locker in the School of Psychology.

**What happens to the information that you provide?**

- The data you provide may be used for one or more of the following purposes:
  - The overall findings may be submitted for publication in a scientific journal, or presented at scientific conferences.
  - The overall findings may form part of a PhD Thesis, Masters Thesis, or Honours research project that will be submitted for assessment.

If you would like to know the results of this study, we would be happy to email them to you.

Please provide your email address here:

---

**Thank you for considering participation in this research.**

**Carrie Bailey**

Statement of consent

I have read the information about this research and any questions I wanted to ask have been answered to my satisfaction.

I agree to participate in this research. I understand that I can withdraw my consent at any time, prior to the end of my participation.

Name: \_\_\_\_\_

Signature: \_\_\_\_\_

Date: \_\_\_\_\_

Copy to:

[a] participant

[b] researcher