ASSESSING THE EFFECT OF VARIED DESIGN ELEMENTS ON INFORMATION PROCESSING IN MEDICAL DEVICE LABELS

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ABSTRACT

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The labeling of medical devices plays a very important role in communicating product information to healthcare providers so that the device is used safely and effectively. Cai (2012) identified various labeling issues as problematic in medical devices. Specifically: small font sizes, poor color contrasts, absence of latex status or sterility status, and varied locations for three pieces of critical information (latex status, sterility status and expiration dating).

Research proposed herein is comprised of three experimental parts: (1) a benchmarking study to verify (or refute) Cai's findings, (2) a study investigating how design strategies impact early stages of information processing using a change detection methodology; this portion also evaluates symbol comprehension, and (3) a forced choice task which enumerates the effect of design elements on the correct selection of a device and time to select the same. The four design factors which were evaluated are: grouping of critical information, boxing of critical information, symbol presence/absence and color coding.

The key findings from our benchmarking study support Cai's conclusion (2012) that the three pieces of critical information were scattered throughout medical device labels, and that their font sizes were relatively smaller than those of the product name. Legibility testing also bolstered Cai's findings: all three pieces of information deemed critical to the safe and effective use of a medical device were indicated to be significantly less legible ($\alpha=0.05$) than product name and brand name when 20 commercial labels were tested by 99 participants.

Attentive behaviors of participants were evaluated measuring the proportion of the sample that successfully detected changes to stimulus prior to time out (60 seconds) and time to successful change detection. Participants detected changes significantly faster when the three pieces of critical information were boxed than when they were unboxed, in both grouped ($p=0.0086$) and ungrouped ($p<0.0001$) formats. Color-coded designs enabled participants to detect changes significantly faster than non-color-coded design, in both grouped ($p<0.0001$) and ungrouped ($p<0.0001$) formats. In addition, the 3-way interaction term of Boxing x Symbol x Color was found to be significant ($p=0.0323$). Though grouping enhanced performance in treatments with colors, it slowed performance in the boxed conditions.

When comprehension rates of symbols were evaluated, only 6 out of 38 symbols in the internationally recognized standard, AAMI/ANSI/ISO 15223: 2007 A1: 2008, were classified as successful. Three symbols from the same standard were categorized as “critically confusing" for participants: they were not only misunderstood, but, in fact, interpreted to have the opposite meaning of what was intended.

When subjects were asked to identify a product with a particular feature (e.g. containing latex) as quickly as possible, three design effects, namely, Color ($p<0.0001$), Grouping ($p=0.0104$), and Symbol ($p<0.0001$) decreased time to selection. Grouping information in one location, the presence of symbols and color coding showed significantly higher probability rates and less time to correct device selection when compared with the two commercial labels ($\alpha=0.05$).

Our work indicates that medical device manufacturers should seriously consider employing these design elements to develop a standard labeling format for critical information. Further, policy changes regarding stand-alone graphical representation on medical device labels should be carefully considered prior to their implementation.

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CHAPTER 1

INTRODUCTION

1.1 Significance of this research

1.1.1 Labeling matters

General labeling requirements for medical devices that are sold in the US can be found in the Code of Federal Regulations, specifically, 21 CFR 801. At minimum, device manufacturers must prominently label:

- The name and place of business (21 CFR 801.1)
- The intended use of the device (21 CFR 801.4) and
- Adequate directions for use (21 CFR 801.5).

Beyond this, there are labeling requirements related to the specifics of the devices themselves, such as those containing latex (21 CFR 801.437) or that are delivered in a sterile state. In September of 2013, the FDA published a final rule mandating the presence of a unique device identifier (UDI) pertaining to most medical devices sold in US commerce. Two items in the final rule, the device identifier and the production identifier, have the potential to force device manufacturers to revise their labeling. The device identifier references information specific to the model. The production identifier requires one or more of the following items be presented in both plain-text format that can be easily readable by patients and health care professionals, and a format that can be read by a barcode scanner or an Automatic Identification Data Capture (AIDC) technology (FDA, UDI Final Rule, 2013):

- The lot or batch within which a device was manufactured;
- The serial number of a specific device;
- The expiration date of a specific device;
- The date a specific device was manufactured;
- The distinct identification code required by 21 CFR 1271. 290 (c) for a human cell tissue, or cellular and tissue-based products (HCT/P) regulated as a device.

The likely revision of the vast majority of labels within the device industry presents an opportunity to update not only the information dictated by the final rule, but to optimize the label content so that it can be readily read and understood by healthcare providers.

In April 2013, another proposed rule regarding medical device labeling was issued by FDA. It is composed of two important changes: (1) to allow for the inclusion of stand-alone graphical representation of information or symbols which are established as part of a standard developed by a nationally or internationally recognized standards development organization (SDO) and accompanied by a symbols glossary, and (2) to authorize the use of the symbol statement “Rx only” on the labeling of prescription devices (FDA, Use of certain symbols, Proposed rule, 2013). Its primary purpose is to make medical device labeling more user-friendly by replacing small, difficult-to-read text with pictorial information, and to harmonize the labeling information of US and foreign regulatory bodies (e.g. European Commission). If this rule is enacted, it will benefit

medical device manufacturers in several ways: e.g. increased space utilization and a single labeling system for multiple markets (e.g. US, EU countries)

1.1.2 End-user VOCs (Voice Of Customers)

Cai (2012) conducted a series of seven focus groups comprised of operating room personnel (primarily perioperative nurses and surgical technologies) with the goal of identifying the most prevalent problems associated with medical device packaging. Two major problems emerged as critical: device labeling and difficulty associated with sterile presentation of devices (Cai, 2012).

As groups drilled down into the intricacies regarding device labeling, a central theme was that non-critical information hindered healthcare personnel from finding critical information easily. Four pieces of information were repeatedly indicated as critical to patient care and problematic in the labeling of commercial devices at present (see Table 1).

Table 1. Information critical to the safe and effective use of medical devices as identified by Cai

No.	Critical information
1	Latex status
2	Expiration dating
3	Sterility status
4	Product name

1.1.2.1 Latex status

Study participants reported that a lack of information regarding latex status causes confusion; for instance, when information regarding latex is absent, many respondents reported uncertainty regarding whether or not latex was of concern (Cai,

2012).

CFR 801.437 dictates that devices containing natural rubber or synthetic rubber are required to have the following caution statement on the outside package, container or wrapper: “Contains or presence of natural rubber latex which may cause allergic reactions” (CFR 801.437). Focus group results suggest, however, that some confusion still exists regarding the current approach.

1.1.2.2 Expiration dating

For sterile medical devices, packages have the unique function of creating a sterile barrier system (SBS) that maintains device sterility as the product traverses distribution (Philchik, 2003). Many times the expiration date is a direct function of the stability date available for the seal, rather than the device itself (Philchik, 2003). As such, upon expiration, the integrity of a package, and therefore the sterility of the device, is no longer guaranteed. Expiration dating that can be noticed and understood is paramount to the safety of the contents within.

Focus group participants reported a lack of standard location, poor contrast and small font sizes as problematic for expiration dating (Cai, 2012). The UDI final rule mandates standardized content as, year, month and day (e.g., 2013-09-30) so as to ensure that dates are unambiguous and understood by users clearly (FDA, UDI Final rule, 2013), but placement and textual formatting requirements are not addressed.

1.1.2.3 Sterility status

As with latex status labeling, focus group participants indicated that an absence of information regarding sterility caused confusion regarding the status of the device within the package (Cai, 2012). Reported problems included difficulty in reading

sterility status information due to relatively small font sizes and inconsistency in formatting (Cai, 2012).

1.1.2.4 Summary

The issues of expiration dating and confusion regarding sterility status both have the potential to contribute to hospital/healthcare acquired infections (HAIs), a noted problem for healthcare. HAIs are caused by a wide variety of common and usual bacteria, fungi and viruses during the course of receiving medical care (CDC, 2012b). Researchers have estimated that 1.7 million of these infections occurred in 2002 and, of these, 274,098 were Surgical Site Infections (SSI), 16% of the total. This same group reported 424,060 HAIs were Urinary Tract Infections (UTIs), approximately 25% of the total (Klevens, 2007).

1.2 Research goals

The goal for this research was to develop a new labeling system for medical devices, which facilitates timely and efficacious processing of three of the pieces of critical information (sterility status, latex status and expiration dating) Cai identified as crucial to the safe and effective use of devices, but at present, reported as problematic (Cai, 2012).

It is hypothesized that a standard location and format of information deemed critical to care will benefit healthcare providers during most stages of information processing. To test this hypothesis, we chose to use the labeling of indwelling urinary catheters as a model product. The perioperative use of indwelling urinary catheters has become routine practice in orthopedic surgery services (Wells, 2004; Skelly, 1992; Michelson, 2004). Indwelling catheters were chosen as our model

for several reasons, including their price, widespread use, association with Urinary Tract Infections (UTIs) and because they may or may not contain latex. Six brands of indwelling catheters: Bard, Teleflex, Amsino, Dynarex, Covidien and Kendal, were collected for the benchmarking portion of this research to verify the problematic labeling conditions reported by Cai (2012). Findings from the benchmarking study were used to create labels for mock brands of indwelling catheters to objectively test the effect of varied design factors (specifically: standard location, the use of a graphic box and symbol presence or absence, and color-coding) on varied stages of information processing (e.g. attention, comprehension, and, ultimately, choice). Further, our creations were compared with existing systems to objectively evaluate the same.

CHAPTER 2

LITERATURE REVIEW

2.1 Medical Device labeling regulations

2.1.1 Misbranding

Misbranding is defined in the Federal Food, Drug and Cosmetic Act (FFDCA) as: “labeling that is false, misleading or incorrect in some detail.” Products that are misbranded cannot legally move through interstate commerce in the US. Section 502 of the FFDCA provides a listing of ways that products regulated by the FDA can be misbranded (see Appendix 2). Eleven out of the 23 listed violations relate to the labeling of a medical device (FDA, Labeling Requirements-Misbranding, 2013). It is imperative that medical device manufacturers familiarize themselves with labeling requirements in order to create products that can be legally distributed in interstate commerce in the United States.

2.1.2 General labeling requirements

The labeling requirements for medical devices which are sold in USA are defined in the Code of Federal Regulations (CFR) Title 21. Specifically, part 801 of 21 CFR describes the general labeling provisions of commercial medical devices as addressed in Table 2.

Table 2. General labeling requirements for medical devices (CFR Title 21, 801, 2013)	
Section	**Contents**
Part 801.1	Name and place of business of manufacturer, packer or distributor
Part 801.4	Meaning of intended uses
Part 801.5	Adequate directions for use
Part 801.6	Misleading statements
Part 801. 15	Prominence of required label statements
Part 801.16	Spanish-language version of certain required statements

If a medical device is being sold in the US, it must contain information regarding the place where it was manufactured, packed or distributed as well as the name of business ownership for manufacturing, packing or distribution (CFR Title 21, 801.1, 2013). This information allows medical device users to identify a contact in case of questions or problems associated with a purchased medical device. Further, if violation(s) is (are) present, the FDA may contact the business unit shown on the labeling of a specific medical device for appropriate legal actions.

Part 801.4 addresses the meaning of 'intended uses' as follows:

> *"The words "intended uses" refer to the objective intent of the persons legally responsible for the labeling of devices. The intent is determined by such persons' expressions or may be shown by the circumstances surrounding the distribution of the article."*

"Intended uses" are communicated to users by legally responsible persons or representatives for a specific medical device through varied printed information, including labeling, advertising matter, and written statements.

The directions for use specified on the labeling of medical devices should be adequate for a layperson to understand safe product use (CFR Title 21, 801.5, 2013). The required contents for the directions for use are listed in Table 3.

Table 3. Adequate directions for use (CFR Title 21, 801.5, 2013)	
#	**Contents**
1	Statements for all conditions, purposes, or uses for which such device is intended
2	Quantity of dose, including usual quantities for each of the uses for which it is intended
3	Frequency of administration or application
4	Duration of administration or application
5	Time of administration or application
6	Route or method of administration or application
7	Preparation for use

To meet the listed requirements in Table 3, the labeling of commercial medical devices should contain what specific purpose it is intended for, how it is used in a safe manner along with route or method of administration or application, and preparation for use (if applicable), as well as specific conditions to be avoided. Mandatory directions for use require bold statements and medical device symbols intended for the purpose of warning or cautioning. Recommendations for appropriate handling, and the quantity of dose per use also have to be addressed, as well as how often, long or what specific time it has to be used.

Misleading statements render a device misbranded (CFR Title 21, 801.6, 2013). Furthermore, insufficient prominence of legally required information also constitutes a case of misbranding (Federal Food, Drug, and Cosmetic Act, 2013). As such, all wording requirements, statements and other information should be visually prominent or conspicuous (CFR Title 21, 801.15, 2013). The prominence or conspicuousness of the required labeling information may fail due to the conditions addressed in Table 4.

Table 4. Failures of prominence or conspicuousness (CFR Title 21, 801.15, 2013)	
No.	**Contents**
1	The failure of the required information to appear on the part or panel of the label which is presented or displayed under customary conditions of purchase
2	The failure of the required information to appear on two or more parts or panels of the label, each of which has sufficient space therefore, and each of which is so designed as to render it likely to be, under customary conditions of purchase, the part or panel displayed
3	The failure of the label to extend over the area of the container or package available for such extension, so as to provide sufficient label space for the prominent spacing of the required information
4	Insufficient label space for the required information, resulting from any word, statement, design or device which is not required by or under authority of the act
5	Insufficiency of the label space for the required information, resulting from the use of label space to give materially greater conspicuousness to any other information not in association with the required information
6	Smallness or style of type in which the required information appears, insufficient background contrast, obscuring designs or vignettes, or crowding with other written, printed, or graphic matter
7	Insufficiency of the label space for the required information, resulting from the use of label space for any representation in a foreign language

To sum, it is recommended that medical device manufacturers use sufficient label space when supplying all required information, considering font size, spacing and background contrast, as well as appropriate placement so as to avoid insufficient prominence or conspicuousness .

If a device is sold in the commonwealth of Puerto Rico, where Spanish is the predominant language, a label written solely in Spanish is acceptable (CFR Title 21, 801.16, 2013).

2.1.3 Special labeling requirements

CFR Title 21, Subpart H addresses the special requirements of Specific Devices.

Among several special requirements in subpart H, relevant to the study presented herein is the requirement, “User labeling for devices that contain natural rubber” (CFR Title 21, 801.437, 2013). It is intended to protect medical device users from any potential risks associated with natural latex proteins, which may cause anaphylactic reactions. Natural latex proteins refer to the latex formations listed in Table 5, as well as the synthetic rubber that contains natural rubber in its formulation.

Table 5. Latex rubber formations
(CFR Title 21, 801.437, 2013)

Type	Definition
Natural rubber latex	Rubber that is produced by the natural rubber latex process that involves the use of natural latex in a concentrated colloidal suspension. Products are formed from natural rubber latex by dipping, extruding, or coating.
Dry natural rubber	Rubber that is produced by the dry natural rubber process that involves the use of coagulated natural latex in the form of dried or milled sheets. Products are formed from dry natural rubber by compression molding, extrusion, or by converting the sheets into a solution for dipping.

Devices that contain these substances should be labeled prominently in a legible manner with one of the requisite warning statements in bold print on the principal display of the device packaging, the outside package, containers or wrapper, and the immediate device package, container or wrapper (CFR Title 21, 801.437, 2013). Acceptable warning statements include the following:

- Natural rubber latex: “Caution: This Product Contains Natural Rubber Latex Which May Cause Allergic Reactions.”
- Dry natural rubber: “This Product Contains Dry Natural Rubber.”

The Quality System Regulation (CFR Title 21, 820) emphasizes the importance of labeling sterility status of medical devices. If only components of a medical device

are sterilized, appropriate labeling is required to indicate the sterilized parts. For example, a device that was partially sterilized might be labeled with a statement like:

> *"Caution: Only the fluid path of the set is sterile and non-pyrogenic. Do not use in a sterile or aseptic area without proper precautions." (CFR Title 21, 820, 2013)*

If a kit contains some mixed components with regard to sterility status (i.e. some sterile, others not), it may not be stated (or implied) that all contents are sterile (CFR Title 21, 820, 2013).

Other requisite statements regarding sterility have to do with special conditions. For instance, in cases where user sterilization is required, or re-sterilization is required prior to reuse, further information is required on the labeling. Table 6 describes the required information for both cases.

Table 6. Labeling information on sterilization (CFR Title 21, 820, 2013)

Type	Required information
Sterilization by the user before use	Special cleaning methods required
Re-sterilization	Changes in the physical characteristics of the device that may result from reprocessing which affect its safety, effectiveness, or performance; and the limited number of times for resterilization and reuse that can be done without affecting the safety or effectiveness of the device

In cases where re-sterilization or reuse of a medical device is not appropriate, manufacturers should include information warning against such behaviors.

In-vitro diagnostic devices (IVD) must include expiration dating information as part of the labeling because some components of the in-vitro diagnostic may contain a battery or diagnostic reagent, which has limited use life (CFR Title 21, 809.10).

2.2 End-users' voices on labeling

Neid conducted a survey to gain better understanding of what nurses face, to get feedback, and, ultimately, to make packaging easier for end users (Butschli, 2008). The survey included a ranking activity, in which nurses ranked eight different medical device package considerations on a scale of one to eight, with one being the most important (Butschli, 2008). The top two considerations were "easily read text/font labeling" and "speed of opening package" (see Table 7). Most votes converged on those top two considerations, while the last four considerations received only single votes (Butschli, 2008).

Table 7. Medical device package considerations by nurses (Bustchli, 2008)

Ranking	Packaging considerations
1	Easily read text/font labeling
2	Speed of opening package
3	Manufacturer's instructions for use provided via Web
4	Manufacturer's instructions for use in every package
5	Smallest possible package
6	Color-coded labeling
7	Consistent package sizes
8	Least amount of packaging waste

Cai (2012) conducted seven-focus groups with perioperative personnel (primarily nurses and surgical technologists) to investigate their needs regarding medical device packaging. Qualitative data was converted to quantitative data using a process called "content analysis" (Neuendorf, 2002). Focus group discussions were transcribed and broken into "thought units" which were organized using a coding scheme and enumerated to build inferences by analyzing the frequency of common themes.

Seven hundred and ninety-five thought units were enumerated in the category "packaging issues". 68.4 % of these were sub-categorized as "opening & aseptic presentation" while "identification" accounted for 22.6% and "packaging waste" 8.6% (Cai, 2012). Nurses reported that they did not have enough time to scan and read the labeling in its entirety due to time pressures. Focus group participants recommended "packages that nurses don't need to read" and the "presence of critical information in a format that can be quickly identified and read" (Cai, 2012).

Specific to "packages that nurses don't need to read", there were several recommendations by survey participants (Cai, 2012):

- Transparent packaging to allow quick identification of contents
- Diagrams to indicate size and shape (if transparent packaging is not available)
- Color coding systems (with the caveat request that they be consistent and universal)
- Different opening features (i.e. certain package structures reserved for use with sterile devices only)

Most participants reported difficulty in identifying critical information on packages and that non-critical information interfered with accessibility of critical information (Cai, 2012). They identified four pieces of critical information: "expiration dating", "latex status", "sterility status" and "product name". Challenges (and solutions proposed) relating to identifying and reading critical information quickly are presented in Table 8 (Cai, 2012).

Table 8. Challenges associated with the labeling of critical information and suggested solutions (Cai, 2012)		
Challenges		**Solutions**
Non-critical information gets in the way making it harder to find the wanted information		Get all the wanted information together, highlight the critical information
Expiration dating	No standard location	Standardize a location for this information
	Light colors	Make it dark and black or bold, bright color
	Small font size	Use bigger font size
Latex status	Lack of any information regarding latex status causes confusion regarding its presence or absence	
	Latex-free info not provided	
Sterility information for double barrier	The sterility information printed on the inner package	The outer package should have the information
	Small font size	Use bigger font size
	Wrong highlighting of sterility for unsterile item	Use circle and slash

Cai (2012) categorized suggestions for improvement into 3 actionable items:

- **Single location and standardized placement**
  - ✓ To gather the critical information in one location
  - ✓ Standardized location for expiration date
- **Noticeable text**
  - ✓ Bolded, bright or color-contrasted expiration date
  - ✓ Circled, slashed sterility information (symbol use)
  - ✓ Bigger font size for expiration date, sterility information
- **Presence of critical information**
  - ✓ To present latex status information
  - ✓ To present sterility status information on all packages (outer and inner)

These actionable items have the potential to be critical factors in the development of labels which facilitate timely and efficacious processing of the critical information.

2.3 Significance of latex status

2.3.1 Manufacturing process of latex-containing medical devices

The term “latex” is familiar to most healthcare professionals as a potential catalyst for allergic reactions. The main source of latex is the sap of commercially grown rubber trees, *Hevea brasilensis* (Zaglaniczny, 2001; Kam, 1997; White, 1996). Ammonia and sulfite are added as chemical preservatives while the sap is extracted from the rubber trees (Zaglaniczny, 2001; Virant, 1996). Several additives such as compounding agents, emulsifiers, stiffeners, etc. are added to improve the rubber’s structure quality in processing (Zaglaniczny, 2001; Virant, 1996). Items are processed from rubber into molds for products such as gloves, balloons, and condoms (Zaglaniczny, 200; Cheng, 2000). The process of making latex-rubber containing gloves is described in Appendix 3.

2.3.2 Latex allergy types

Latex is used for fabrication of several functional medical devices, many of which are listed in Table 9. The allergy symptoms from latex-containing medical devices are caused by a response of the human immune system against foreign proteins (Alwilda et al., 2003). Hypersensitive responses to latex are classified into Type I immunoglobulin E (IgE) or Type IV cell-mediated response (Alwida et al., 2003). Type II and III allergy responses are not associated with latex rubber. Type I latex reactions are initiated by IgE antibodies which are produced against water-soluble proteins remaining in natural latex products (Alwida et al., 2003). These reactions may be generated within minutes

after exposure to the latex allergen. The severe symptoms caused from the type I latex reactions are temporary, rapid constriction of bronchial smooth muscles, increased vascular permeability, and dilation of postcapillary venules. Type IV latex reactions may be triggered by chemicals used as accelerants and antioxidants during the manufacturing process. Type IV hypersensitivity reaction can occur 24 to 72 hours after exposure to the latex allergen (Alwida et al., 2003). Expected symptoms from type IV latex reactions are pruritis, erythema, and vesicles or blister at the point of contact (Alwilda et al., 2003).

Table 9. Medical devices that commonly contain latex
(Adapted from Alwilda et al., 2003)

1. Ace bandages	27. Injection ports
2. Adhesive tape	28. Intravenous meditation pumps
3. Anesthesia masks	29. Multidose/single-use vial tops
4. Bandages	30. Nasogastric tubes
5. Bath mats	31. Operating room masks, hats, and shoe covers
6. Bite blocks	
7. Blood pressure cuffs	32. Oral and nasal airways
8. Bulb syringes	33. Orthopedic appliances
9. Catheters	34. Protective sheets
10. Colostomy pouches	35. Pulse oximeter
11. Crutch pads	36. Reflex hammers
12. Dental dams	37. Respirators
13. Dentures	38. Spacers for inhaled medication
14. Disposable gloves	39. Stethoscopes
15. Electrode pads	40. Stretcher mattresses
16. Endotracheal tubes	41. Suction catheters
17. Enema kits	42. Surgical gowns and drapes
18. Feminine sanitary pads	43. Surgical lifts
19. Fluid-circulating warming blankets	44. Surgical masks
20. Foam pillows	45. Syringes
21. Gastroscopy tubes	46. Tape
22. Goggles	47. Tourniquets
23. Hot water bottles	48. Tympanometers
24. Identification bands	49. Vascular stockings
25. Incontinence pads	50. Wheelchair cushions and tires
26. Incubators	51. Wound drains

2.3.3 Risks associated with latex allergy

Risks caused by the latex allergen have been investigated by several researchers in various medical areas (see Table 10). According to an FDA announcement regarding latex allergies, more than 1,000 cases were reported between 1988 and 1992, and an additional 500 cases by early 1996 (Dillard, 1992; Kellett, 1997). It was estimated that 3% to 17% of healthcare workers had allergic reactions as a result of their exposure to latex (Bowyer, 1998). This percent increased to 24% of healthcare workers who were atopic (i.e. those with a tendency toward multiple allergic conditions) (Bowyer, 1998). Patients who were atopic had higher risks to latex allergy than the general population (Bowyer, 1998). Children who were atopic or required frequent surgical interventions were more likely to have a latex allergy (Queiroz, 2009). Workers involved in the manufacture of latex products were also at a high risk for latex allergy (Bowyer, 1998).

Table 10. Articles addressing risks associated with latex allergy	
Dillard et al. (1992)	- Between 1988 and 1992, the FDA was informed of 1,133 allergic reactions that had occurred due to 30 different medical products made of latex. - 408 involved reactions to latex examination gloves and 77 were to latex surgical gloves.
Kellett (1997)	- 500 reports of latex allergy and seven more deaths (six associated with barium enemas and one with latex gloves) were reported additionally by early 1996.
Bowyer (1998)	- Estimates for healthcare workers reveal as few as 3% and up to 17% as having latex allergy. - This increases to 24% of healthcare workers who are atopic (having a hereditary tendency for immediate Type I allergic reactions). - Approximately 7.5% of surgeons and 5.5% of theatre nurses have a latex allergy. - Patients who have pre-existing allergies are more likely to develop latex allergy. Atopic patients are more prone to latex allergy. 60 to 80% of latex allergic patients are atopic as opposed to 20% of the general population. - Occupationally exposed people such as those involved in the manufacture of latex products are at high risk of latex allergy. Those with occupational exposure have a 2.9-17.0% chance of latex allergy, whilst research into those working in latex glove manufacture plants found 11% of workers with latex allergy.
Queiroz (2009)	- Allergic or immediate hypersensitivity reactions to latex have been reported in children with increasing frequency in the past. - Children's subpopulations at particular risk include: atopics, individuals with spina bifida, children undergoing surgical procedures during the neonatal period and individuals who required frequent surgical instrumentations.

2.3.4 FDA Countermeasure actions

The FDA has taken several actions to inform the public of latex allergy risks and to revise related regulations to minimize potential risks. Farnham et al. list five specific actions taken by the agency (Farnham et al., 2002):

- **Medical device reporting/MedWatch data and the emergence of natural latex allergy**: In March 1991, the FDA issued a Medical Alert to the medical community to inform healthcare workers of the problem of natural latex allergy, to make recommendations for patient care and advice, and to request health professionals report adverse reactions to natural rubber in medical devices.
- **User labeling rule for devices containing natural rubber**: In September 1998, the rule "User Labeling for Devices That Contains Natural Rubber" became effective. This rule requires medical device labeling to disclose the presence of natural rubber in medical devices and device packaging when present. There are two types of natural latex rubbers of concern: Natural Rubber Latex (NRL) and Dry Natural Rubber (DNR). The following statement is required for medical device/packaging containing one of those latex rubbers:

  For DNR: "This Product Contains Dry Natural Rubber"

  For NRL: "Caution: This Product Contains Natural Rubber Latex Which May Cause Allergic Reactions."
- **Good manufacturing practices for devices containing natural rubber**: In October 1997, the FDA issued the Quality System Regulation final rule. This rule requires the removal of "manufacturing material" from the finished product when manufacturing has the potential to affect product quality. Water-soluble natural rubber proteins are defined as

manufacturing material in 21 CFR Part 820.3(p). As such, current Good Manufacturing Practices (cGMP) require device manufacturers to remove such soluble proteins to the extent possible and to document this removal.

- **Standard activities:** The FDA has been involved in the creation of standards regarding medical devices that contain latex. Specifically, FDA scientists participated in the development of standard test methods for quantification of Natural Latex proteins.

2.4 Significance of sterility status

2.4.1 Packaging functions and materials

Medical devices that contact a patient's blood or other internal tissues should be sterile until their package is opened for medical treatment (Sherman, 1998). As such, the vital function of a medical device package is to keep the contents sterile. Three basic elements of package design have been indicated as crucial indicators for ensuring sterility maintenance (Pilchik, 2003):

- **Seal strength**: The property to hold the sealed components of the package together
- **Seal integrity**: The property associated with the seal being of sufficient quality to prevent microorganisms from penetrating through the seal
- **Package integrity**: The property to ensure that the entire package is free from defects that can allow penetration of microorganisms.

Two broad categories of packaging materials are commonly used in the manufacture of medical devices; selection of the appropriate material(s) is frequently dictated by the sterilization process which will be used (Pilchik, 2003):

- **Porous packaging materials**: Tyvek (a polymeric fiber strand distributed in multiple layers to produce a flat sheet stock) and paper (medical grade) to allow for gas sterilization methods
- **Nonporous packaging materials**: Polymeric films (used individually or in combinations through lamination, co-extrusion, or coating) and foils (used in combinations with polymeric components to increase the oxygen and water vapor resistance) to allow for other sterilization methods

2.4.2 Sterilization methods

The sterilization of a medical device is defined as the process by which anticipated levels of microbial contaminants in a load of items are exposed to a specific number of decimal reduction values (D-values, time or dose to kill 90% of the organisms at a given set of conditions) for the sterilant being utilized (Sherman, 1998). The probability of a survivor per item (PSI) is generally less than 10^{-3} for topical products, and less than 10^{-6} for implantable or blood-contacting items (Sherman, 1998). When selecting the appropriate sterilization method, design factors to be considered include: product materials, product design, packaging, marketing requirements, current manufacturing and sterilization capabilities, and process economics (Sherman, 1998). The available methods of sterilization for packaged medical devices are (Sherman, 1998):

- **Steam under pressure**: Saturated steam under pressure is the most practical and dependable agent for sterilization of heat-tolerant medical supplies and packaging.
- **Dry heat sterilization**: Dry heat is transferred by means of convection and conduction to sterilize medical items. This method requires longer sterilization and higher temperatures than does moist heat.
- **Gaseous sterilization**: Ethylene oxide (ETO) and propylene oxide (PO) are generally used for gaseous sterilization. ETO is the most commonly used gaseous sterilant for sterilization of medical items and instrumentation.
- **Ionizing radiation sterilization:** Absorption of high-energy radiation (gamma and electron beam radiation) by organic matter causes chemical changes in the material. Unlike the ETO sterilization, ionizing radiation does not impart toxicity to plastic materials, but may change their color and stability.
- **Gas plasma sterilization:** "Plasma" is an ionized, or partially ionized gas which contacts the surface of devices for sterilization. This method was developed to reduce and/or to eliminate the dependence on ETO as a sterilant for moisture and heat labile items. The commercially available plasma sterilization systems are the Plazlyte system and the Sterrad system.

2.4.3 Healthcare-associated infections (HAIs)

Healthcare-associated infections (i.e. an infection that a patient acquires during the course of receiving treatment for other conditions in a health care setting) are caused by a wide variety of common and usual bacteria, fungi and viruses during the

course of receiving medical care (CDC, 2012b).

Researchers have reported that 38,785 of these infections occurred in 2011 (see Table 11). The numbers of infections noted were 18,113 for "Central-line associated bloodstream infection, 14,315 for "Catheter-associated urinary tract infection", and 6,357 for "Surgical site infections", and "Central-line associated bloodstream infections" comprised 47%, "Urinary Tract Infections", 37%, and "Surgical site infections", 16% (CDC, 2012a).

Table 11. Healthcare-associated infections in U.S. hospitals during 2011 (CDC, 2012a)

Type of infection	**Category**	**# of infections**	**Percent (%)**
Central-line associated bloodstream infections (CLABSI)	Intensive Care Units(ICUs)	10,134	
	Wards	5,781	
	Non-intensive Care Units (NICUs)	2,198	
	Sub-total	**18,113**	**47%**
Catheter-associated urinary tract infections (CAUTI)	Intensive Care Units (ICUs)	8,925	
	Wards	5,390	
	Sub-total	**14,315**	**37%**
Surgical site infections (SSI)	**Combined SCIP procedures**	**6,357**	**16%**
HAIs (Observed)	Total	**38,785**	**100%**

The estimate of average attributable costs ($ base year) per patient in "Central-line associated bloodstream infections", "Urinary Tract Infections (UTI)" and "Surgical Site Infections (SSI)" were $29,116, $1,007 and $34,670, respectively, in 2007 (CDC, 2009).

2.4.4 Surgical microbial contamination

Sources of surgical microbial contamination may be either resident flora (i.e. endogenous microorganisms) or transient flora (i.e. exogenous microorganisms) (Hopper, et al., 2010). Resident flora are bacteria or microorganisms considered to be permanent residents of the skin and are not readily removed by hand washing (AORN, 2010a; Hopper et al., 2010). Transient flora are bacteria and microorganisms that colonize the superficial layers of the skin and are easily removed by hand washing or use of a hand rub agent, and they are easily transmitted from patients and inanimate surfaces to other locations (AORN, 2010a; Hopper et. al, 2010). One potential cause of exogenous microbial contamination is a break in sterile technique (Hopper et al., 2010). Sterile technique is defined by the Association of peri-Operative Registered Nurses (AORN) as "methods by which contamination by microorganisms is prevented." Aseptic transfer, or transfer of the device to the sterile field without contaminating it, is paramount. To ensure asepsis, the following appropriate, preventive actions are recommended by the Association of perioperative nurses (AORN, 2010b):

- A properly designed Sterile Barrier System (facilitates sterilization, maintains sterility throughout distribution, assists in verification of sterility maintenance and enables aseptic transfer)
- Correct sterilization processing
- Maintenance of seals throughout the distribution process
- Verification of the sterile barrier system's integrity by personnel, and
- Aseptic transfer to the sterile field.

In addition, the Association of Surgical Technologists (AST) has recommended their members use specific standards of practice for creating the sterile field. The following key actions are recommended to maintain aseptic technique in opening sterile device packages (AST Standards, 2011):

- Placement of sterile items on clean, dry surfaces
- Verification of external chemical indicator or integrator, integrity of packaging, and expiration date prior to opening
- Establishment of an appropriate routine for opening sterile items
    - Sequence of opening sterile items: backtable pack, basin set, small wrapped items (e.g. sterile towel pack) and peel pack items
    - Opening of gown and gloves on a separate flat surface
    - Flipping small wrapped items, peel packs and suture packs onto the sterile field using aseptic technique
    - Not allowed to flip heavy or difficult items onto the sterile field
    - Opening sterile items in a grouping manner for establishment of a logical, sequential, and efficient routine (e.g. sharp items, drapes on each designated area of the back table on the sterile field, etc.)

2.5 Significance of expiration dating

The shelf life of medical devices is determined by multiple factors, including: bio-burden (both in the air and on the surfaces of sterile packaged products and packaging materials), seal strength, distribution stresses, airflows, personnel traffic patterns, storage location, temperature, pressure, humidity, and bio-barrier properties of

packaging materials (1998, Sherman). Generally, the expiration date is a direct function of the stability date available for the seal, rather than the device (Pilchik, 2003).

Most medical devices have an expiration date as part of their labeling. The UDI final rule (2013) requires standardized content format, in the form of year, month and day (e.g. 2013-09-30) so as to ensure that dates are unambiguous and understood by users clearly (FDA, UDI Final rule, 2013). But, multiple labeling problems regarding expiration dating were identified from Cai's research (2012): lack of a standardized location, the use of poor contrast, and small font size. These problems are likely to cause equivocal expiration dating of medical devices, and have the potential to result in increasing the number of devices used beyond a point where sterility is guaranteed.

2.6 Information Processing

The significance of these three pieces of critical information (latex presence, sterility status and expiration dating) has clear ramifications for health. As such, the clear communication of this information is paramount at the point of use. Thus, a review of one theoretical frame to assess information processing is germane to the development of useful labeling systems.

Commonly cited models of information processing (Rousseau, 1998; Dejoy, 1991) suggest that for information to be effective, five steps of interaction must occur between the message recipient (in this case, a healthcare provider) and the message. These are:

- Step 1: Exposure (absence of needed information can be problematic)
- Step 2: Perception (the user must take the message in through one of the five senses)

- Step 3: Encodation (the external signal from the environment must be converted into an internal one that can be processed by the cognitive system)
- Step 4: Comprehension (messages that are beyond the reading level of the individual or symbols that are confusing are problematic)
- Step 5: Action (the physical systems perform the desired and appropriate action)

Success or failure at each processing step is directly influenced by four broad inputs (the user, i.e. message recipient; the context of interaction; the task to be accomplished; and the design of the product/package system) (de la Fuete, 2013; see Figure 1). Specifically, “Context” refers to the environment of interaction; “Package” means a physical object to contain the product; “User” relates to the individual interacting with the package. As a given task is accomplished (e.g. selection of the appropriate product), the user goes through the 5 steps of the information processing model to take an action. When the task is accomplished, the state of things is altered, and the next task may begin, and the information processing sequence begins anew.

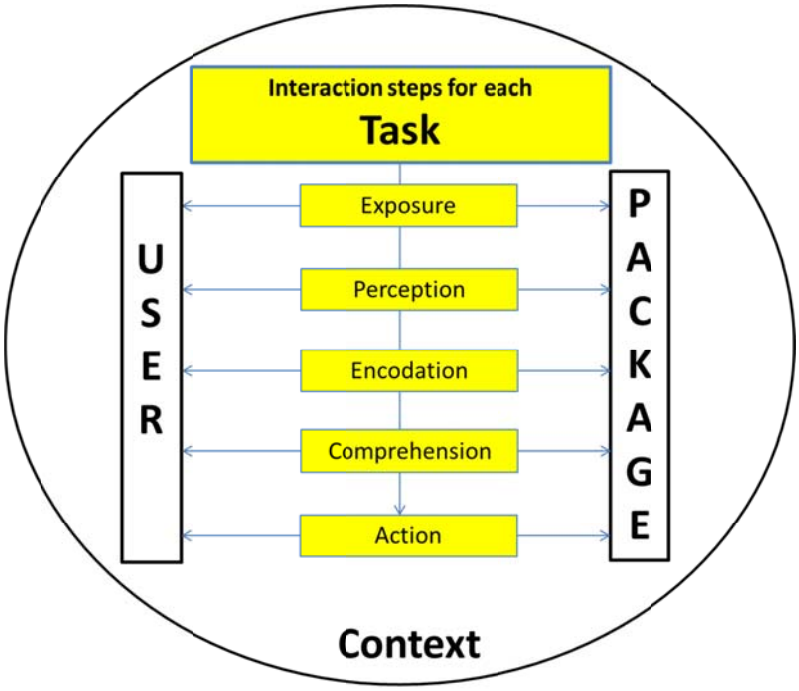


Figure 1. Diagram of Information Processing Model

2.7 Labeling Noticeability

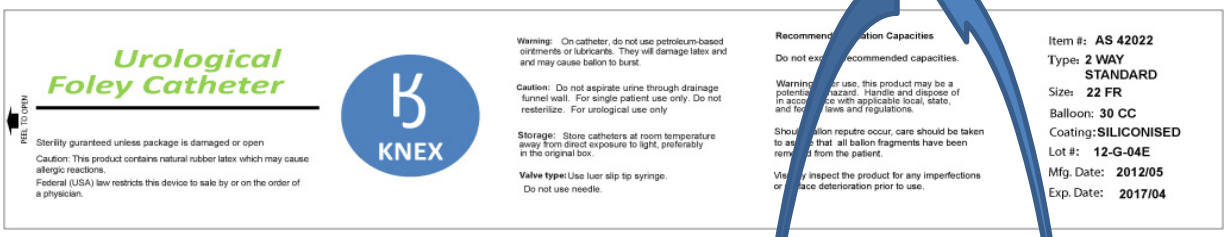
Early stages of information processing (exposure, perception) involve attention. In recent years, techniques commonly used to measure the attentive behaviors of people have been applied to labeling and packaging.

2.7.1 Change Detection

Change detection is a technique that is frequently used for evaluating the attentional prioritization people give varying components within a scene (Goldstein, 2007). It is commonly referred to as a “flicker task”. During each flicker trial, a control image (240ms) continuously alternates with the test image (240ms) (the control only slightly altered) with a brief, gray screen interleaving between the two (80ms) as shown

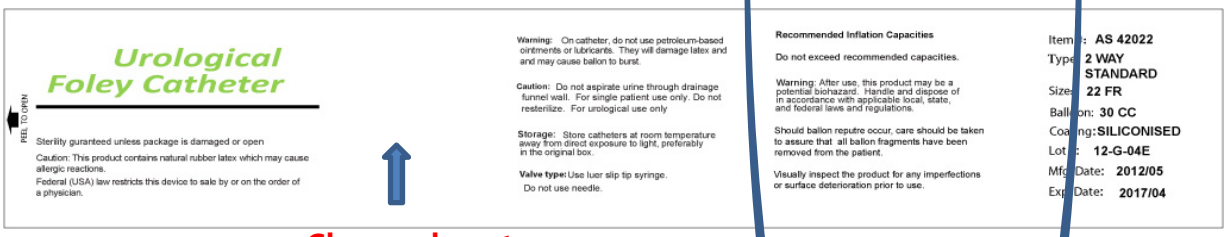
in Figure 2. The techniques and its timings were originally developed by Rensink et al. (1997). This sequence image-blank-test-blank loops until the participant presses the space bar, indicating that they have found the alternation, or until they time out.

First screen: Control image appears for 240ms.



Second screen: Gray image appears for 80ms.

Third screen: Test image appears for 240ms.



Changed part

Fourth screen: Gray image for 80ms (Returning back to the control image if a subject does not press the computer's space bar).

Figure 2. Change Detection Image Cycle

The change detection methodology has been applied on a limited basis to objectively evaluate the visual salience of varied elements of labeling and packaging (Table 12).

Gaschler et al. (2009) used change detection to study how individuals attend to and process newly introduced formats for food labels. Tested elements included text and graphic formats of four pieces of nutrition information (fat content, “best before” date, recycling information and organic status). Changes to “organic” product information were detected significantly faster than other information on the food labels, while changes in the “fat content” information were detected significantly slower than all other types of product information ($p < 0.01$). Additionally, there was a correlation in change detection time and age for “organic” and “recycling” information; older subjects detected changes significantly slower than young subjects ($p < 0.01$).

DeHenau (2010) evaluated the effect of TALL-Man lettering in differentiation of look-alike, sound-alike drug names. TALL-Man lettering is a practice of writing drug names in uppercase letters. Eight pair images of drug names were presented to subjects in two formats (TALL-Man vs. traditional). Participants were able to decipher a doppelganger faster when the changes occurred in TALL-Man pairs when compared with the same in traditional lettering ($p<0.0001$). The effect was particularly pronounced for nurses.

Bix et al. (2010) evaluated the prominence of different label elements on a beverage container. Six portions of labels were evaluated: the manufacturer name, the product name, text within a warning dot in three colors, and presence/absence of the warning dot. The time required to detect changes to the manufacturer’s name was

significantly longer than for any of the other label elements ($p<0.0001$). Changes to the warning dot with red text were located marginally faster than the warning printed in black ($p=0.0566$). In addition, an effect of the location of the change was noted, suggesting that subjects tended toward a standard scanning pattern across the stimulus.

Sundar (2013) evaluated the effect of design, specifically color and facial icons, on participant's attention to nutrition information. Front Of Pack (FOP) nutrition labels of varied design were compared with nutritional information conveyed through traditional labeling (in the form of Nutrition Facts Panels, or NFPs). Changes to the FOPs were more likely to be successfully detected than those to the NFPs (Nutrition Fact Panels) ($p<0.0001$); when detected successfully, researchers noted a significant effect of color ($p<0.0001$).

Table 12. Change detection studies relating to packaging or labels	
Title	**Objective/Stimuli**
Change detection for new food labels (Gaschler et al., 2009)	**Objective:** To investigate the person-variables (e.g. age of participants) associated with lower change detection latencies for specific food-related information/To evaluate whether the change detection task is useful for studying how individuals attend to and process formats and contents of food labels **Stimuli:** A label with the fat content, best-before date, recycling, and organic information/ A design in which the content (general, organic and health) of the product information was presented in text and graphic format
Applying change detection to test the noticeability of components of medical labels (DeHenau, 2010)	**Objective:** To qualify TALL Man lettering as a method to differentiate look-alike sound-alike drug names/To evaluate the change flicker method so that it can possibly be used in future labeling studies **Stimuli:** Eight pairs of look-alike, sound-alike names in two formats (TALL Man vs. traditional)
The use of change detection as a method of objectively evaluating labels (Bix et al., 2010)	**Objective:** To develop change detection software and methodology for label use/To compare the relative prominence of different label elements on a beverage container **Stimuli:** A beverage container to have 6 label elements: the manufacturer name, the product name, and a warning dot with text in three colors
Investigating the effect of color and icon on information processing behaviors related to Front-Of-Package nutrition labels (Sundar, 2013)	**Objective:** To evaluate the effect of color and facial icons on the ability of a nutrition FOP to attract attention **Stimuli:** 3 factorial designs (Color vs. No color, Text vs. Facial Icon, and Healthy vs. Unhealthy) with 3 brands of cereal/24 FOP (Front Of Pack) trials and 24 NFP (Nutrition Facts Panel) trials regarding 4 nutrients: ‘FAT’, ‘SATFAT’, ‘SUGARS’ and ‘SALT’

2.7.2 Eye tracking

Fixations and saccades are the two main components of eye movements (Buswell, 1935). Fixations describe the status of the still eyes at a certain point of a stimulus, lasting 200-500 milliseconds, while saccades are quick eye movements, lasting 20-40 milliseconds (Rayner, 1998). The pattern of fixations and saccades are called a scan path (Noton & Stark, 1971). Usually, eye trackers record this pattern of

fixation and saccades (Wedel, 2008). Most commercial eye trackers use an infrared corneal reflection methodology to measure the distance and angle of the reflection of infrared light from the center of the pupil to determine the point of fixation of the person (Young and Sheena, 1975).

In recent years, limited academic research has evaluated early stage information processing with packaging and labeling as the stimulus material (Table 13).

Bix et al. (2009) evaluated the prominence of warnings (one which indicated the lack of a child resistant feature and another alerting consumers to the presence of tamper evident features) on OTC pain relievers using a head-mounted optics ASL eye tracker. Other label elements examined were brand name, claim statement and drug facts for comparison purposes. Research participants spent less time on the zone of a warning indicating that the packaging had no child resistant features than other label elements ($p < 0.05$). Results of a free recall test subsequent to the eye tracking study suggested further that subjects recalled regulatory information (e.g. warnings for "Alcohol", "CR (Child Resistant)", "Child statement", and "TE (Tamper Evidence)") significantly less frequently than marketing information ($p < 0.05$). Specifically, the most frequently recalled elements were brand name, indications and package color. Text legibility was evaluated using a Lockhart legibility instrument. Rotation of the instrument's handle correlated with rotation of the first of a pair of polarizing filters in series. Greater angles of rotation related to more light: as such, items that were more difficult to read required a greater degree of filter rotation than those that were readily deciphered. The child resistant warning and a tamper evident warning, both of which are required by law to be prominent or conspicuous, required significantly more rotation

than any of the other elements tested, suggesting that these two warnings were relatively less legible than the others tested ($p < 0.05$).

Oh (2010) measured the relative prominence of the traditional format versus an altered format for nutrition labels, using a Pan Tilt ASL eye tracker. The Nutrition Facts Panels (NFPs) of nine cereals were presented with two types of format: iconic face versus text only for three nutrients (sodium, sugar and fat). The iconic face format showed improved prominence in all three dependent variables: total time in zone ($p < 0.0001$), probability of noticing in zone ($p< 0.0001$) and number of hits to the zone ($p< 0.0001$).

Graham et al. (2011) evaluated the visual attention of research participants to the Nutrition Facts label under a simulated grocery shopping exercise, using an Eye Link 1000 eye tracker. Sixty-four foods were presented for purchase decisions: “would buy”, “would not buy”, or “not applicable”. Each individual food included three images on a computer screen: the food’s price and description, a photograph of the food and an ingredient list, and a Nutrition Facts Label. Researchers indicated that the label components located on the top of the label were viewed more frequently than those on its bottom ($p<0.05$), and labels located in the center of the computer screen were viewed more frequently than those on its sides ($p<0.05$).

Herpen et al. (2011) evaluated the effect of Front-of-Pack nutrition labels of cereal products, using a remote eye tracker manufactured by SMI. There were 6 cereal boxes, composed of three different nutrition labeling schemes: logo, multiple traffic-light (MTL) label, and nutrition table. It was reported that participants were less likely to attend to nutrition tables than to logos ($p<0.01$) and attention to logos was

marginally higher than attention to MTL labels ($p=0.067$). However, the total amount of time spent on labels was longer for the nutrition table than the logo ($p<0.05$), and the average dwell time on the logo was lower than the average dwell time on either the MTL label ($p<0.001$) or the nutrition table ($p<0.01$).

Hurley et al. (2012) evaluated the effect of an amount of product visible through the primary display panel on consumer attention and purchase decision in the category of grill ware. There were 4 levels of visible product exposure tested: 0%, 40%, 90% and 100%; packages were positioned on the shelves of a fully immersive simulated shopping environment while eye movements were tracked using a Tobii glasses eye tracking device. It was found that the packaging with the greatest product exposure was chosen more than the other packaging configurations and the 0% visible product received significantly fewer fixations, a slower time to first fixation and lower total fixation durations than the other 3 configurations (p's<0.01).

Hurley et al. (2013) also conducted research to determine whether consumers preferred a public label product versus a private label product in terms of product purchase and visual attention, using a mobile eye tracking system manufactured by Tobii. Researchers suggested that the public label product was preferred in purchase decisions and received more visual attention (fixation time) than the private label product ($p<0.05$).

Bix et al. (2013) evaluated the effect of color contrast on participants' attentive behaviors and perceptions of fresh produce, using an ASL Pan Tilt eye tracker. Six different types of produce (red apples, oranges, lemons, green apples, purple onions and white onions) were photographed with four different colored mesh bags, resulting in

four contrast treatments: the same (as the produce), complementary, complementary-analogous and analogous. Researchers concluded that the same color or analogous color treatment inspired more visual attention as measured by the number of visual fixations ($p<0.001$) and fixation time ($p<0.001$) than complementary or complementary-analogous treatment. A post-hoc survey of purchase intention, quality and visual appeal as measured with a Likert scale was done, and odds ratio estimates were conducted for statistical analysis. The same color or analogous color treatment was perceived by participants as higher quality, more visually appealing and garnered a higher level of purchase intention than other color treatments ($\alpha=0.05$).

Sundar (2013) evaluated the effect of Front-Of-Pack (FOP) nutrition labeling on the attentive behaviors of participants viewing breakfast cereals and crackers, using a head-mounted ASL eye tracker. There were two label types evaluated: Nutrition Facts Panel (NFP) only and FOP +NFP. It was reported that there was evidence of a significant effect of label type (NFP only or FOP + NFP) for analyzed response variables: probability of noticing nutrition information on the package ($p<0.0013$), time to first fixation of nutrition information ($p<0.0001$) and total time spent on nutrition information ($p=0.0032$). These findings suggested that when the FOP was present, participants were more likely to fixate the nutritional information, hit nutritional information faster, and spend longer time viewing the information.

Gomes et al. (2013) evaluated the effect of shelf presence of full body graphic labels versus partial body graphic labels on plastic beverage bottles, using a mobile eye tracking system manufactured by Tobii. There were 12 beverage bottles, composed of six different flavors and two different labels for each flavor. It was reported that there

was evidence of a significant effect of label type (full body vs. partial body) for analyzed response variables: the total number of fixations ($p<0.05$), and visit count ($p<0.01$). These findings suggested that the partial body labels had more within-AOI (Area-Of-Interest) fixations than the full body labels, and participants returned to looking at partial labels more often than full body labels.

Table 13. Eye tracking studies relating to packaging or labels

Title	Objective/Stimuli
Examining the conspicuousness and prominence of two required warnings on OTC pain relievers (Bix et al., 2009)	**Objective:** To evaluate the prominence of warnings on child-resistant and potential product tampering (Time spent viewing the warnings compared with other areas of the label, recall and legibility ability) **Stimuli:** 4 kinds of OTC pain relievers to include Brand name, claim statement, child resistant and tamper-evidence warnings
Measuring the relative prominence of graphic symbols vs. text for nutrition labels using eye tracking (Oh, 2010)	**Objective:** To examine the attentive behaviors of subjects when viewing 9 cereals with nutrition information presented in the traditional format and an altered format. **Stimuli:** Nutrition Facts Panels(NFPs) of Cereals: Text only (commercially available) NFPs vs. Icons inserted NFPs
Eye-Tracking evidence that consumers preferentially view prominently positioned nutrition information (Graham, Robert, & Jeffery, 2011)	**Objective:** To track the visual attention of individuals making simulated food-purchasing decisions to assess Nutrition Facts label viewing **Stimuli:** Three images on a computer screen: food's price and description, a photograph of the food and ingredient list, and Nutrition Facts Label
Front-of-pack nutrition labels. Their effect on attention and choices when consumers have varying goals and time constraints (Herpen et al., 2011)	**Objective:** To examine consumer attention to and use of three different nutrition labeling schemes (logo, multiple traffic-light label, and nutrition table) **Stimuli:** 6 cereal boxes with three labeling schemes

Table 13. (Cont'd)	
The effect of modifying structure to display product versus graphical representation on packaging (Hurley, Galvarino, Thackston, Ouzts, & Pham, 2012)	**Objective:** To investigate whether the amount of physical product visible from the primary display panel of a package has an effect on consumer attention and purchase decision in the category of grill ware **Stimuli:** Three similar products with four distinct package structures varying the amount of visible product exposure (0%, 40%, 90% and 100%)
Effects of private and public label branding on consumer purchase patterns (Hurley, Ouzts, Fischer, & Gomes, 2013)	**Objective:** To determine whether consumers prefer a public label product versus a private label product **Stimuli:** 2 boxes of cookies: public brand product (General Mills Cookies Crisp) versus private brand product (Southern Home Kookies)
The effect of color contrast on consumers' attentive behaviors and perceptions of Fresh Produce (Bix, Seo, & Sundar, 2013)	**Objective:** To identify the impact of simultaneous color contrast (i.e. the produce viewed through a mesh bag) on attentive behaviors as measured by eye tracking and perceived quality, visual appeal and purchase intention as measured with a Likert scale **Stimuli:** Six different types of produce (red apples, oranges, lemons, green apples, purple onions and white onions) were photographed with four differently colored mesh treatments
Investigating the effect of color and icon on information processing behaviors related to Front-Of-Package nutrition labels (Sundar, 2013)	**Objective:** To evaluate whether an FOP (Front-Of-Pack) encourages attention to the more detailed NFP (Nutrition Fact Panel), or acts as an informational short-cut, thereby reducing attention to the traditional NFP. **Stimuli:** 8 packages with 3 factorial design: FOP vs. No FOP, Healthy icons vs. Unhealthy icons, and Breakfast cereal vs. Crackers
The effect of full body versus Partial body graphic labelling on beverage packaging (Gomes et al., 2014)	**Objective:** To evaluate the shelf presence of full body graphic labels versus partial body graphic labels on plastic beverage bottles **Stimuli:** 12 beverage bottles, composed of six different flavors and two different labels for each flavor

2.8 Text Legibility

After labeling information is exposed to and noticed by users, next interactions between a user and a package are perception and encodation (see Figure 1). During

these interactions, the proper text legibility of labeling information on the package is crucial for users to maintain successful information processing.

A label consists of textual and design elements that are used to communicate information to users, and much of this information is required by regulators. Text designs of the label can be varied to improve its legibility.

> *"Legibility is the overall goal in a complex system of interrelated elements (letter weight, letter compression, counter form shape, stress, type style, type size, message layout, leading, kerning, ink, substrate, and printing process) that come together to create a message" (Bix, 2001).*

Textual elements include font size (e.g. x-height), shape of ascenders and descenders, typeface design, counter form shapes, line spacing, color contrast, the use of serifs or san-serifs, stroke weight, kerning and leading (Bix, 2001). Terminology definitions relating to letter elements are described in Table 14.

Table 14. Terminology definition of letter elements on a label

Terms	Definition
Font	One size of one particular typeface
x-height	The height of the body of the lowercase letter
Ascenders	Any portion of the letter extending above the x-height
Descenders	Any portion of the letter falling below the x-height
Typeface	Full range of type of the same design
Family	All the typefaces of the related designs
Counter forms	Negative spaces within letters
Serifs/San-serifs	Serifs: Terminal strokes that are short cross lines at the end of main stroke San-serifs: Serifs are not present.
Stroke weight	Variations in stroke thickness
Kerning	Negative spacing between letters
Leading	Amount of space between lines of type/Distance between two baselines of letters

x-height is the height of the body of the lowercase letter, and it is a better indicator to show legibility of the letter because the font size varies, depending on the typeface (Craig, 1980).

> *"The size of a given font is based on the now-antiquated system of setting metal type. Metal type setting was the system used when letterpress, a type of relief printing, was the only way to print text. In letter press printing, each letter is raised from the surface of a metal block. The block is referred to as the body: the printing surface (the letter) is referred to as the face. Type size is based on the size of the block from which the letter is carved and is not directly related to the height of the letter" (Craig, 1980).*

Serifs (presence of terminal strokes) have pros and cons in legibility. They contribute to improvement of legibility by combining separate letters into word-wholes horizontally (Perles, 1977); however, some researchers suggest that their strokes can cause visual distractions (Garcia, 1981).

Letter spacing is considered as an important design element in legibility. Kerning (negative spacing between letters) may reduce legibility dramatically (Pettit, 2000). And, the optimal amount of leading (distance between two baselines of letters) depends on the letter elements as well as the message design (Becker et al., 1970).

Another important factor affecting legibility is the color contrast between the letter and its background. It has been suggested that messages printed in black on white result in better legibility than other color contrasts (Sorg, 1985; Sundar, 2009).

Bix (1998) conducted research to evaluate the effect of age on legibility readings as measured with the Lockhart Legibility Instrument (LLI). In the Lockhart Legibility Instrument, Greater angles of rotation of the first of a pair of polarizing filters in series related to more light. That is, items that were more difficult to read required a greater

degree of filter rotation than those that were readily deciphered. There were 4 age groups (21-35, 36-50, 51-65 and 66-80) in this study. It was found that there was significant difference in legibility indices among age groups; specifically the older age group had a higher legibility index requiring a great degree of rotation of a polarizing filter in series than their younger counterparts.

2.9 Symbol Comprehension

Along with texts being clearly legible, symbol comprehension is an important factor in communication of required labeling information to users as intended, for safe, effective use of medical devices.

Medical device symbols are used as an effective way to convey information in different languages because of their benefits such as high visual impact, less space occupation and information independent of language (Davies et al., 1998; Wolff & Wogalter, 1998; Perry, 2003; Liu et al., 2005). Notwithstanding these advantages, there are potential risks of medical errors if those symbols are not interpreted correctly.

2.9.1 Global standards

The international standard for medical device symbols is ISO 15223-1 2007: "Medical devices – Symbols to be used with medical device labels, labeling and information to be supplied." The standard is comprised of recognized symbols which convey information considered by regulatory authorities to be essential for the safe and proper use of medical devices. These symbols, which have precise meanings defined by the standard, are intended to reduce confusion and delays that can result from labeling in multiple languages.

Symbol use is widespread in the European Union, largely in response to the EU Commission's 1993 Medical Directive, which requires that text must be presented in multiple languages in order to be accessible to providers in multiple countries (EU Council Directive 93/42/EEC, 1993). Recognizing challenges related to label space, the EU Directive also indicates "where appropriate this information should take the form of symbols," and that symbols should conform to harmonized standards (EU Council Directive 93/42/EEC, 1993). When harmonized standards do not exist, symbols must be described in accompanying documentation. The harmonized symbol standard recognized by the European Union on medical device symbols is EN 980 2008: "Symbols for use in the labeling of medical devices". Its main purposes are to reduce the need for multiple translations of words into national languages, to simplify labeling wherever possible, and to prevent divergent symbols intended to convey the same information in Europe.

With a few exceptions (e.g. FDA, Use of symbols on labels and in labeling in Vitro Diagnostic devices intended for professional use, 2004), US regulations indicate that graphics, pictures or symbols that represent required information on medical devices must be accompanied by explanatory English text adjacent to the symbol. However, FDA published a proposed rule involving the use of standardized symbols for medical devices. If enacted, the rule would: (1) allow for the inclusion of stand-alone graphical representation of information or symbols, provided they are part of a standard developed by a nationally or internationally recognized standards development organization (SDO) and accompanied by a symbols glossary, and (2) authorize the use of the symbols statement "Rx only" on the labeling of prescription (FDA, Use of certain

symbols, Proposed rule, 2013). The harmonized symbol standard recognized by the US is an American National Standard, ANSI/AAMI/ISO 15223-1: 2007: “Medical devices-Symbols to be used with medical device labels, labeling and information to be supplied on medical device symbols.” The primary intentions of this proposed rule are to make medical device labeling more user-friendly by replacing small, difficult-to-read text with pictorial information and to harmonize the labeling information of US and foreign regulatory bodies (e.g. European Commission).

ISO 15223 contains 31 basic symbols for medical devices (Table 15). Since ANSI/AAMI/ISO 15223: 2007 adopted ISO 15223, its symbols are the same as those of ISO 15223 in terms of symbol image and symbol meaning. But, 7 symbols were added in Amendment 1: 2008 for ANSI/AAMI/ISO 15223. The added symbols are “Sampling site”, “Fluid path”, “Non-pyrogenic”, “Contains or presence of natural rubber latex”, “Drops per milliliter”, “Liquid filter with pore size” and “One-way valve”.

EN 980 has 32 symbols for medical devices (Table 15). The EN 980 symbols not included in the ISO 15223 document are: “Manufacturer”, “Authorized representative in the European community”, “Sufficient for”, “For IVD performance evaluation only”, “Contains or presence of natural rubber latex”, and “Sterile fluid path”. The five symbols which are included in ISO 15223 not present in EN 980 are: “Fragile, handle with care”, “Protect from heat and radioactive sources”, “Patient number”, “Humidity limitation” and “Atmosphere pressure limitation”.

The FDA guidance (Use of symbols on labels and in labeling of In Vitro Diagnostic Devices intended for Professional use, 2004) contains fewer symbols (see Table 15) than ISO 15223. The symbols which are not included in the FDA guidance

are “Fragile, Handle with care”, “Keep away from sunlight”, “Protect from heat and radioactive sources”, “Keep away from rain”, “Do not resterilize”, “ Non-sterile”, “Do not use if package is damaged”, “Patient number”, “Humidity limitation”, and “Atmosphere limitation”.

Table 15. Symbols comparison among international and US standards

No	Symbol Description	ISO 15223	EN 980	ANSI/AAMI/ ISO 15223	FDA Guidance
1	Biological risks	√	√	√	√
2	Do not re-use	√	√	√	√
3	Consult instructions for use	√	√	√	√
4	Caution, consult accompanying documents	√	√	√	√
5	Fragile, handle with care	√		√	
6	Keep away from sunlight	√	√	√	
7	Protect from heat and radioactive sources	√		√	
8	Keep away from rain/Keep dry	√	√	√	
9	Lower limit of temperature	√	√	√	√
10	Upper limit of temperature	√	√	√	√
11	Temperature limitation	√	√	√	√
12	Use by date	√	√	√	√
13	Date of manufacture	√	√	√	√
14	Batch code	√	√	√	√
15	Catalog number	√	√	√	√
16	Serial number	√	√	√	√
17	Control	√	√	√	√
18	Negative control	√	√	√	√
19	Positive control	√	√	√	√
20	Sterile	√	√	√	√
21	Sterilized using aseptic processing techniques	√	√	√	√
22	Sterilized using ethylene oxide	√	√	√	√
23	Sterilized using irradiation	√	√	√	√
24	Sterilized using steam or dry heat	√	√	√	√
25	Do not resterilize	√	√	√	
26	Non-sterile	√	√	√	
27	Do not use if package is damaged	√		√	
28	In Vitro Diagnostic medical device	√	√	√	√
29	Patient number	√		√	

Table 15. (Cont'd)					
30	Humidity limitation	√		√	
31	Atmosphere pressure limitation	√		√	
32	Manufacturer		√		√
33	Authorized representative in the European community		√		√
34	Sufficient for/Contains sufficient for <n> tests		√		√
35	For IVD performance evaluation only		√		√
36	Contains or presence of natural rubber latex		√	√	
37	Do not use if package is damaged		√		
38	Sterile fluid path		√	√	
39	Sampling site			√	
40	Non-pyrogenic			√	
41	Drops per milliliter			√	
42	Liquid filter with pore size			√	
43	One-way valve			√	
Total # of symbols		**31**	**32**	**38**	**25**

2.9.2 Comprehension evaluations

ISO 9186-1: 2007 is recognized as the international standard to assess the comprehensibility of graphical symbols. During the comprehension test, each respondent is presented with the question: "What do you think this symbol means?" Responses are categorized as one of the five standard categories: 1, 2a, 2b, 3 or 4 (specified in ISO 9186-2007):

- 1: Correct
- 2a: Wrong, 2b: Wrong and the response given is the opposite of the intended meaning
- 3: The response given is "Don't know"
- 4: No response is given

The responses which belong to “category 1” are considered as a correct answer; the other responses are considered incorrect.

Liu et al. (2004) evaluated 16 symbols used in Intensive Care Units (ICU) for comprehension, using methods prescribed by ISO 9186. Twenty healthcare workers in Germany and 13 healthcare workers in China participated in this study. Of the 16 symbols evaluated, only of half symbols in Germany and four symbols in China reached the 67% criterion (specified by ISO 3864), and only 3 out of 16 symbols would be accepted if the 85% criterion (specified by ANSI Z535.3) was considered.

Hermans et al. (2011) evaluated the comprehensibility of 18 symbols used for In Vitro Diagnostic Devices (especially, Rapid Diagnostic Test (RDT) kits) in accordance with methods described in ISO 9186. Two conditions were tested: stand-alone symbols and symbols presented in context (i.e. a color photograph of a malaria RDT kit package). Study participants were health care workers from four international settings (Belgium, Cambodia, Cuba and Congo). The comprehension level of the participants was not satisfactory for most of the tested symbols, based on the 67% criterion (specified by ISO 3864). The symbols which received fewer than 10% correct responses were: “Do not reuse”, “In vitro diagnostic medical device”, “Sufficient for”, “Date of manufacture”, “Authorized representative in EC”, and “Do not use if package is damaged”.

Our review of the literature suggests a scarcity of work investigating comprehension of medical device symbols, with all identified publications coming from outside of the US; the limited research consistently finds poor comprehension rates related to medical device symbols.

2.10 Forced Choice Task

As described previously in the information processing model (Figure 1), a sequence of 5 interactions (i.e. exposure, perception, encodation, comprehension and action) between a user and a package continues until the user takes an action. Thus, it is interesting to assess how the user comprehends labeling information through these interaction steps on varied designs of labeling.

A forced choice task is a commonly used tool to evaluate psychological concepts such as perception, recognition or decision making (McKenzie et al., 2001). This method has been applied to labeling-related research on a limited basis.

Filik et al. (2006) used a forced choice task methodology to investigate the effect of tall man letters on perceptual similarity. Participants were given a "same/different" judgment task, in which they were presented with a pair of drug names on a computer screen and had to indicate, as quickly and accurately as possible, whether the two names were the same or different. The task was chosen to represent a situation in which people were faced with similarly named products that were placed next to each other on a shelf. This forced task study was composed of experiment 1 and experiment 2, using the same test procedure. The difference between the two experiments was that the following instruction was provided prior to experiment 2, but it was not given prior to experiment 1:

"*Tall man letters are used in an attempt to make similar names less confusable with each other.*"

In experiment 1, there was no evidence of an effect of letter style on response time to indicate a same or different name. However, in experiment 2 ($p<0.01$), there was

evidence of a significant effect of letter style, suggesting that shorter response time for the tall man name pairs was taken than for the lowercase names. Another experiment was conducted, using a recognition memory task to assess the effect of color. Names were presented either in lowercase or in tall man letters, and they consisted of black text alone or of black-and-red text. During this recognition memory task, there were two phases: a study phase and a test phase. In the study phase, 5 names were presented; in the test phase, 10 names presented were composed of the 5 names (previously provided during the study phase) and 5 distractor names. Participants were asked to indicate, for each name on the test list, whether or not it had appeared in the study list. This study reported fewer overall errors for names containing tall man letters than for names in lowercase ($p<0.05$), and no evidence of a significant effect on color for the overall number of errors ($p>0.05$).

Borgmeier and Westenhoefer (2009) investigated which signpost food label format enabled consumers best to differentiate healthier products from less healthy ones, using a forced task choice methodology. Participants were given a "heathier/less healthy" judgment task, in which they were presented with 28 food pairs in 5 different nutrition label formats: (1) a simple "healthy choice" tick, (2) a multiple traffic light label, (3) a monochrome Guideline Daily Amount (GDA) label, (4) a colored GDA label and (5) a "no nutrition label" condition. There was evidence of a significant effect of different nutrition label formats on the average number of correct choices for each subject ($p<0.001$). The traffic light label yielded the highest average of 24.8 correct choices of the 28 pairs, and the "no nutrition label" condition was associated with the lowest average of correct choices (20.2 of 28 pairs).

CHAPTER 3

BENCHMARKING EXISTING, COMMERCIAL LABELING FOR INDWELLING, URINARY CATHETERS

3.1 Objective – Benchmark existing, commercial packages for indwelling urinary catheters to verify (or refute) the reports of difficulty with four pieces of critical information

There are three sub-objectives for the first experiment:

- Sub-Objective 1 - Characterize the placement of four pieces of labeling information (sterility status, latex status, expiration dating and product name) on packages of commercially available indwelling, urinary catheters
- Sub-Objective 2 - Objectively evaluate the text of four pieces of critical labeling information

  Measure:

  - leading
  - kerning
  - color contrast
  - type size
- Sub-Objective 3 - Objectively evaluate the symbols present on the labeling of several brands of indwelling urinary catheters, the product being used as a model in this study

  Identify:

  - originating standard (where possible)
  - presence/absence (with and/or without text)

- symbol size
- color contrast

- Sub-Objective 4 - Objectively evaluate the comparative legibility of five pieces of labeling information on packages of commercially available indwelling urinary catheters

3.2 Methodology

3.2.1 Placement of labeling information

The placement of four pieces of information (sterility status, latex status, expiration dating and product name) was evaluated using the nomenclature presented in Figure 3. The locations of the labeling information were classified in binary fashion (as present or absent) in all 4 sectors of the lidding web for the commercially available catheters (six brands) included.

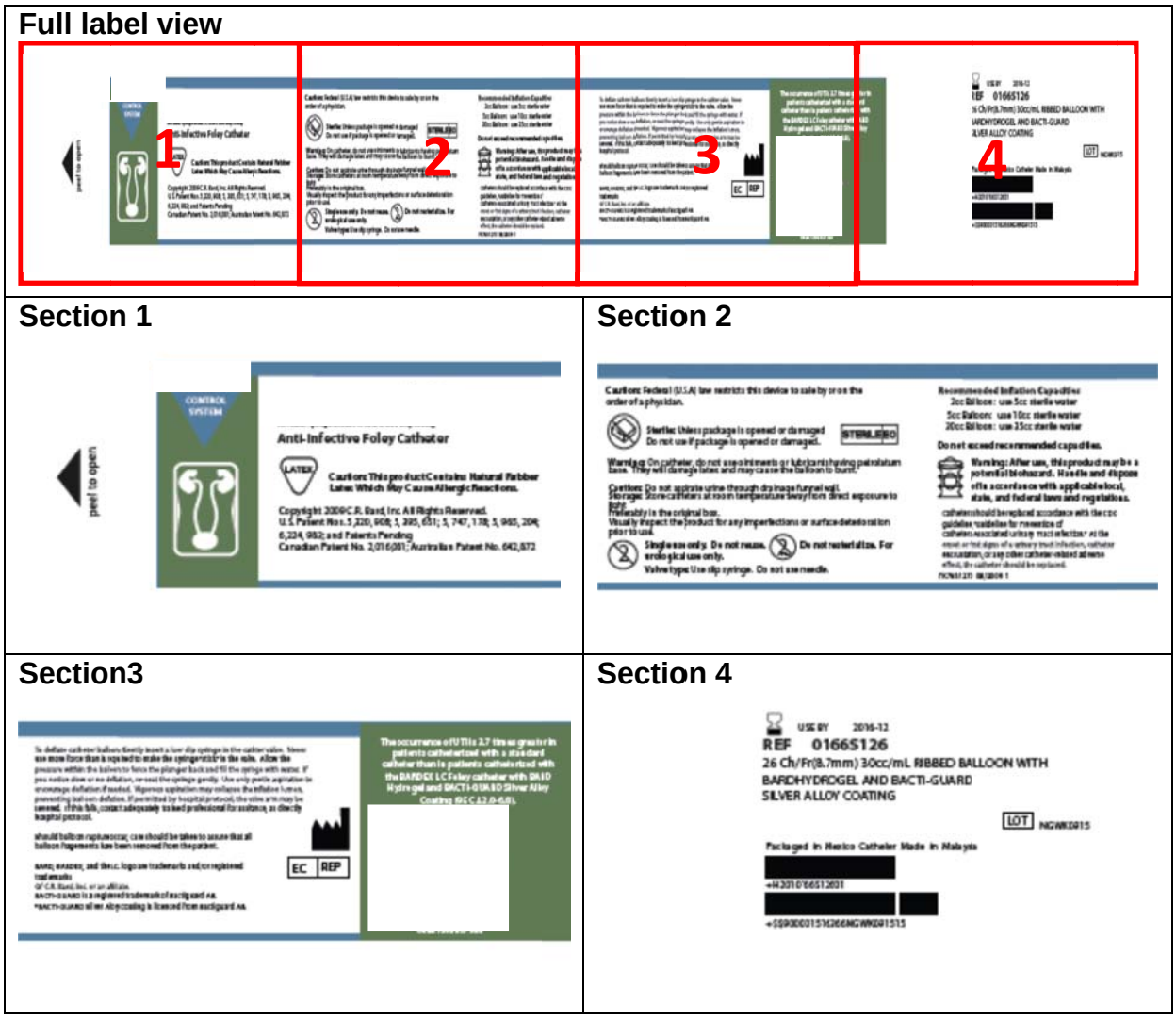


Figure 3. Locations of labeling information

3.2.2 Measurement of leading, kerning and type size, and color contrast evaluation

3.2.2.1 Equipment

Leading, kerning and letter size were measured and recorded using a Bridgeport optical comparator (Bridgeport, CT) in surface illumination mode. A test label was placed on the front moving plate (Up/Down and Right/Left) with a holding fixture made from polystyrene. Once the targeted label text was focused, adjusting the control bar

of the front plate, the surface illumination mode depicted the text on the screen where it was measured (Figure 4).

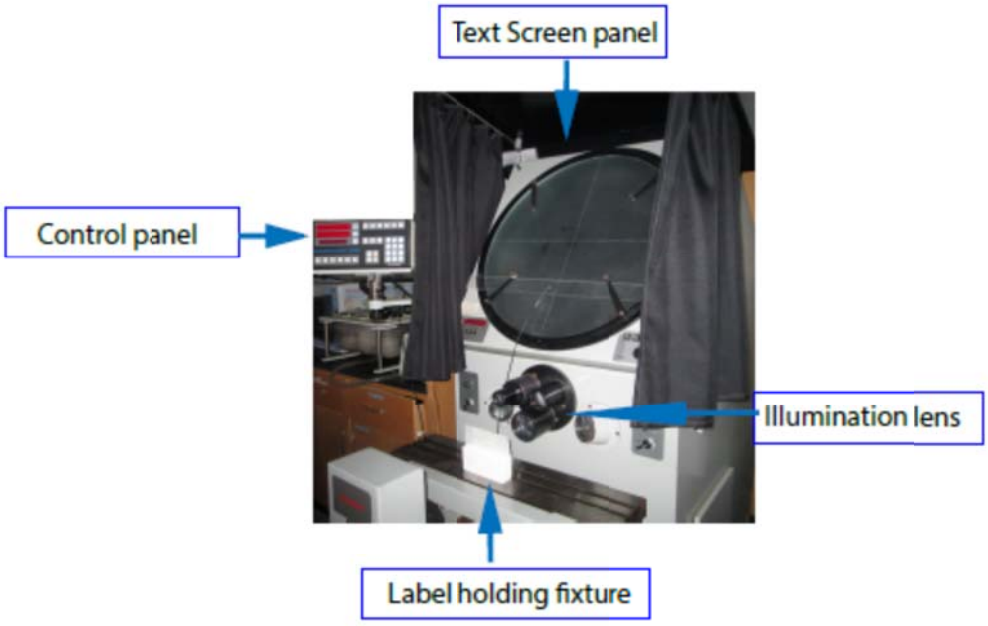


Figure 4. Optical comparator

3.2.2.2 Materials and Methods

Leading is the distance between baselines of the successive lines as presented in Figure 5.

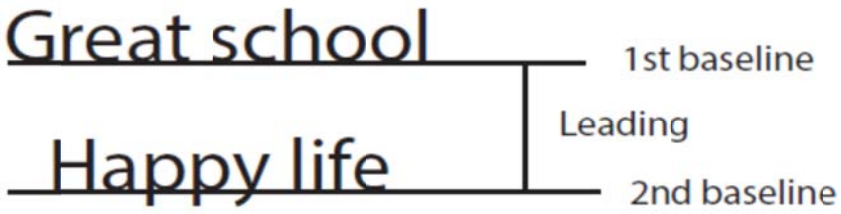


Figure 5. Leading of typefaces

Kerning is negative spacing between characters in a text line (Figure 6).

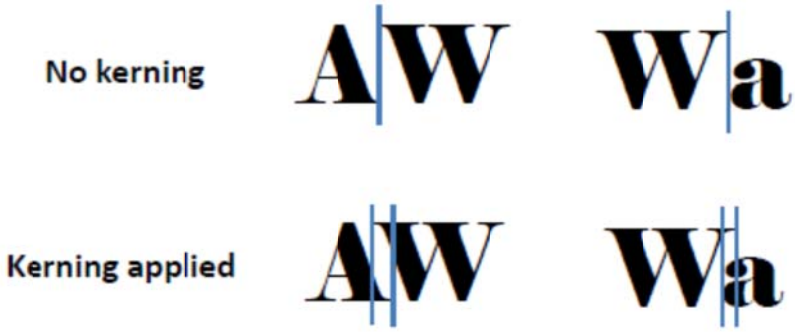


Figure 6. Kerning of typefaces

x-height was measured to characterize the type size. Research has suggested that x-height, the height of the body of a lowercase letter (specifically, the x; see Figure 7), is a better indicator of legibility than type size, which is based on the height of a letter-press block from the now-antiquated system of type setting (Bix, Lockhart, Selke, Cardoso, & Olejnik, 2003).

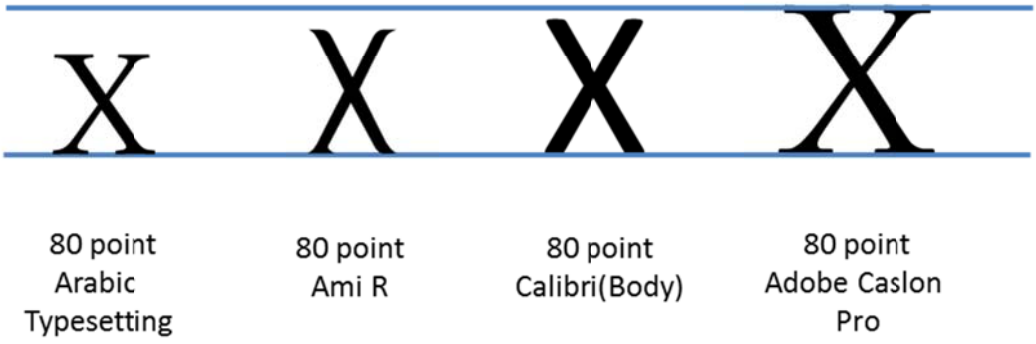


Figure 7. Relative x-heights of typefaces

Texts were further characterized by recording the color contrasts with which they were presented (e.g. black (text)/white (background)).

3.2.3 Symbol evaluation

3.2.3.1 Originating standard

Two globally recognized symbol standards for medical devices are ISO 15223 (Medical Devices – Symbols to be used with medical device labels, labeling and information to be supplied) and EN 980 (Graphical Symbols for use in the labeling of medical device). In 2007, the Association for the Advancement of Medical Instrumentation (AAMI) published a standard for symbol use with medical devices, harmonizing with ISO 15223. This new standard recognized additional symbols in 2008. Herein, symbols on commercial labels were characterized as “standard or non-standard” symbols, based on AAMI/ANSI/ISO 15223: 2007 A1: 2008 (see Table 15).

3.2.3.2 Presence/absence (with and/or without text)

The status of critical information was recorded as: symbol/text, text only and symbol only.

3.2.3.3 Symbol size

Using an optical comparator manufactured by Bridgeport (Bridgeport, CT) in the surface illumination mode, the size of symbols used for three pieces of critical information (sterility status, latex status and expiration dating) was measured in width and height, and recorded by drawing a dimensioned square (Figure 8) as indicated by ISO 9186-1 2007.

Figure 8. Symbol to fill square

3.2.3.4 Color contrast of symbols

Symbols were further characterized by recording the color contrasts with which they were presented (e.g. black (text)/white (background)).

3.2.4 Legibility of texts

3.2.4.1 Subjects

Ninety nine subjects were recruited from PKG 101 and PKG 330 classes at the School of Packaging, Michigan State University and tested using procedures approved under IRB # 13-698. Prior to this legibility experiment, a research consent form was provided to subjects to acquire their agreement for planned research activities (see

Appendix 8). Three pre-tests: visual acuity, color blindness and health literacy, were conducted to characterize participants. A questionnaire was given to subjects to collect their demographic information (see Appendix 5).

3.2.4.2 Equipment

The Lockhart Legibility Instrument (East Lansing, MI), or LLI was used to evaluate the relative legibility of the label information for various catheter brands (Figure 9). Participants recruited from within and around the University were instructed to rotate the hand wheel of the LLI until the first point that they could “easily read” the label information. Rotation of the hand wheel rotates a single polarizing filter of the LLI, and in series, its second filter is held in place. The more the filter is rotated, the more light is allowed through. The polarizing filter can be rotated to a total of 90° of rotation (total light). As such, information that requires a larger degree of rotation is expected to be more difficult for a participant to decipher than information that requires a lesser degree of rotation. Within subjects comparisons were made to derive the relative legibility of the 3 critical pieces of information (sterility status, latex status and expiration dating), compared to other elements of the label, such as the brand and product information.

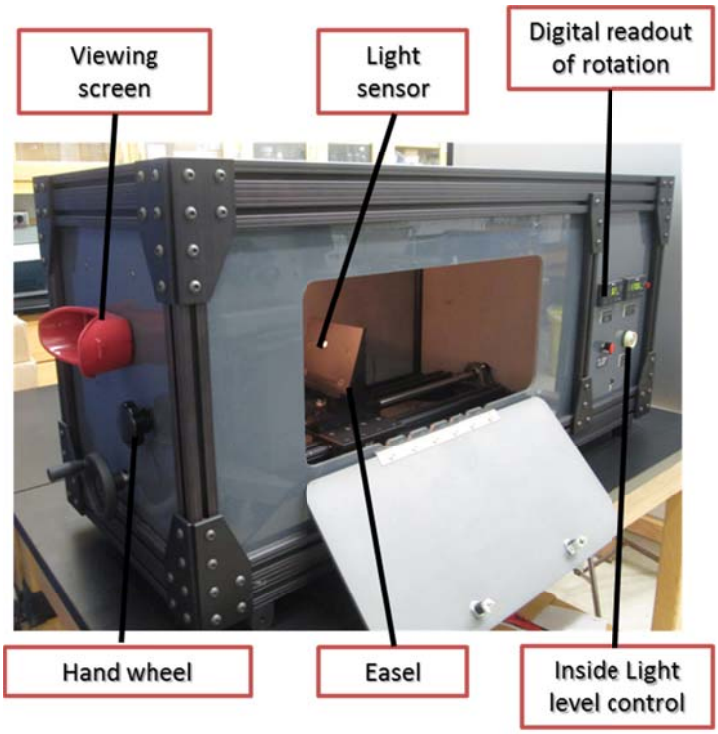


Figure 9. The Lockhart Legibility Instrument (LLI)

3.2.4.3 Materials and Methods

Prior to the legibility experiment, three pre-tests were used to characterize test participants. These were: visual acuity, color blindness and health literacy.

A visual acuity card from Bernell/vision training products (Mishawaka, IN) was utilized to measure near point visual acuity (see Figure 10). The approximate16-inch distance between a subject's eyes and the visual acuity card was kept under general room illumination during the visual acuity test, and the score of visual acuity per subject was recorded as 20/20, 20/30, 20/40, etc.

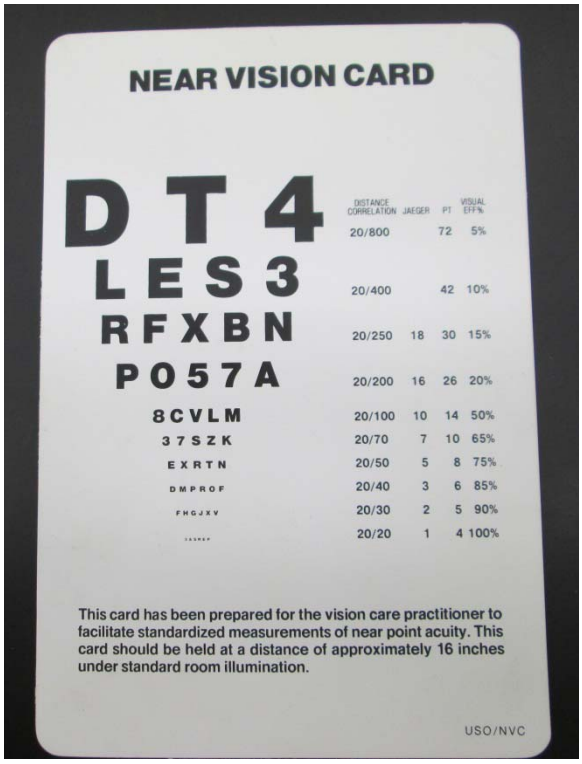


Figure 10. Visual acuity card

Pseudo-isochromatic plates from Richmond products (Boca Raton, Florida) were used to evaluate the color perception of subjects (see Figure 11). If a subject responded correctly to 10 or more out of 14 test plates, the color vision status of the subject was considered as “normal”: otherwise, if 5 or more incorrect response were given, the subject was considered “at risk for color blindness”.

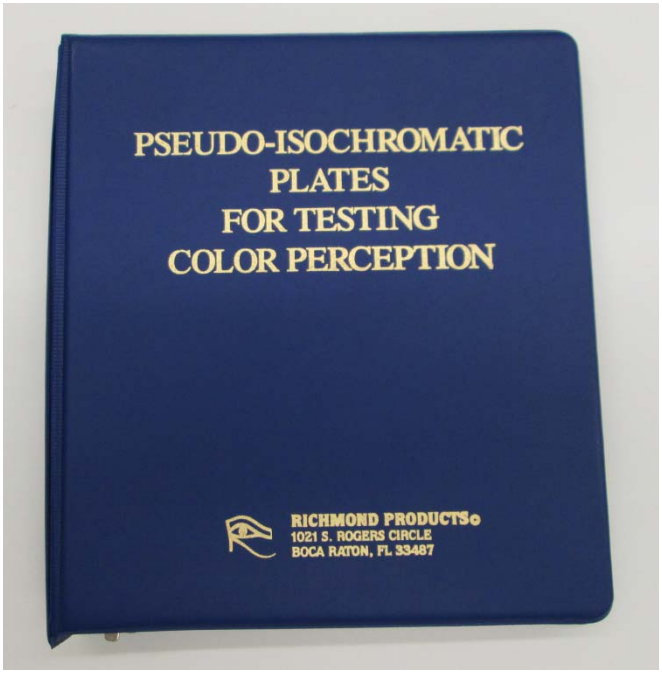


Figure 11. Pseudo-isochromatic plates for testing color perception

Subjects' health literacy status was conducted using the Rapid Estimate of Adult Literacy in Medicine-Reduced (REALM-R) (Bass III, Wilson, & Griffith, 2003). This card consisted of 11 words: Fat, Flu, Pill, Allergic, Jaundice, Anemia, Fatigue, Directed, Colitis, Constipation, and Osteoporosis. Subjects were asked to read 11 words from the card aloud. The first 3 words: Fat, Flu and Pill, serve as an acclimation period, which were not tallied for a final score. Subjects were instructed to say "blank" if they didn't know the given words. If less than 6 out of 9 words (excluding the first 3 words) were pronounced correctly, a subject was reported as "at risk" for poor health literacy.

For each commercial package, five pieces of information (brand name, product name, sterility status, latex status and expiration dating: see Table 16) were further evaluated according to procedures prescribed by ASTM D7298-06, "Standard Test

Method of Comparative Legibility by Means of a Polarizing Filter" with 99 subjects recruited from within and around the University. The detailed procedure of the legibility test is explained in Figure 12.

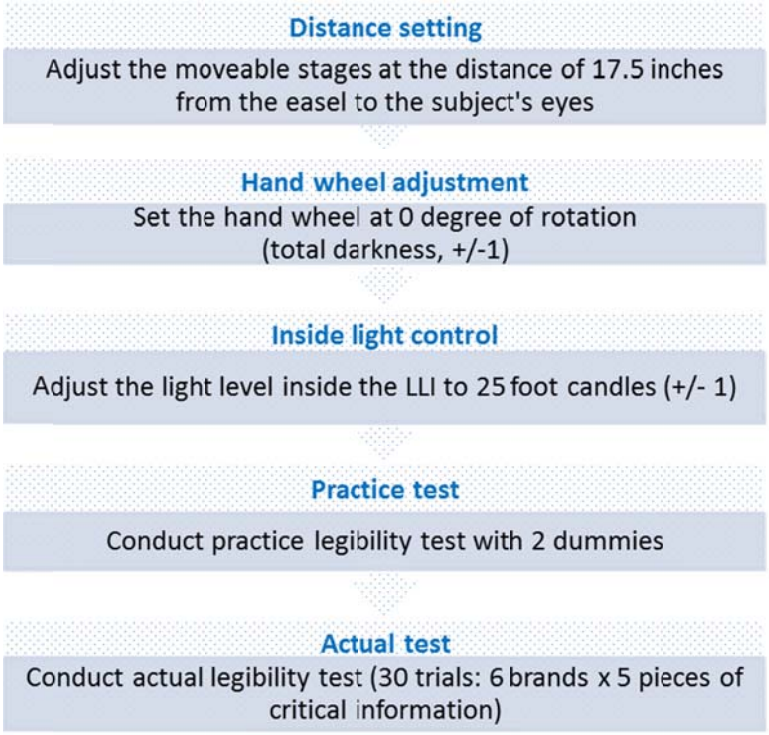


Figure 12. Legibility test procedure

Each participant conducted 30 trials (six brands x five pieces of information) using the legibility instrument (see Appendix 4). Trials were randomized using the SAS "Proc Factex" to mitigate any run order effect. The response variable was measured as degrees of rotation of the polarizing filter in the legibility instrument. The response variable was modeled using a general linear mixed model fitted with the Mixed procedure of SAS software.

Table 16. Labeling information for legibility evaluation		
Information items	**Symbol**	**Contents (Text)**
Brand name	NA	BARDEX I.C. (e.g. Bard)
Product name	NA	Anti-Infective Foley Catheter(e.g. Bard)
Latex status		Caution: This product Contains Natural Rubber Latex Which May Cause Allergic Reactions.
Sterility status		Sterile: Unless packaging is opened or damaged
Expiration dating		USE BY YYYY-MM

3.3 Results

Twenty catheters (six brands) were characterized. Those catheter label images are presented in Appendix 18. Details from this benchmarking study are reported in Appendices 19 to 26.

3.3.1 Placement of labeling information

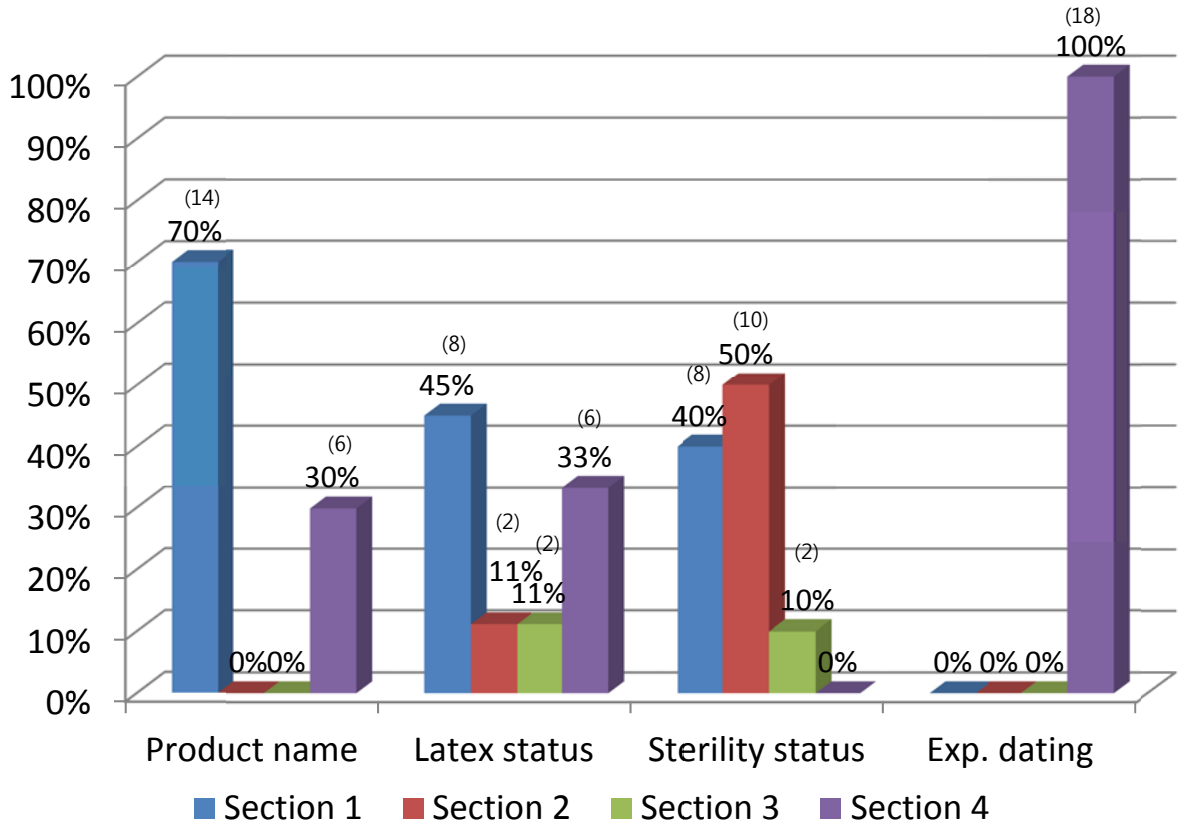
The product name (e.g. 'Foley Catheter'), was primarily located in section 1 (Figure 13). Fourteen out of the 20 catheters had their product name in section 1; the rest of them, in section 4. In addition, various sub-product names such as 'Pediatric', 'All silicone', 'Size (e.g. 66 Fr.)', 'Volume (e.g. 5 cc)', etc. were present as supplementary information. Ninety five % of the investigated catheters contained their sub-product information in section 4.

The required latex warning, "Caution: This product contains natural rubber latex which may cause allergic reactions", was commonly located in sections 1 and 4 (Figure 13). Two out of the 20 catheters did not have any latex-related information. As such,

they were not included in percentage calculations of placement frequencies.

The common text regarding sterility status was “Sterile unless packaging is opened or damaged”. The top two locations for this information were sections 1 and 2 (Figure 13). Six out of the 20 catheters had different locations for their text and symbol regarding sterility status; locations used for text were considered for percentage calculations. Most of the investigated catheters included their expiration date in section 4 (Figure 13). One had no information regarding the expiration date. Thus, it was excluded from percentage calculation. A second was excluded from the calculation totals because information regarding the expiration date was contained on the reverse side of the packaging.

None of 20 catheters studied had text and symbols for all four pieces of critical information in one location; 40% of them used 2 locations and the majority (60 percent) used 3 locations to display the information.



Note) Values in parenthesis represent a number of frequencies

Figure 13. Placement findings in regard to four pieces of critical information

3.2.2 Measurement of leading, kerning and type size, and color contrast evaluation

Leading, the distance between lines of type (see Figure 5) was also measured for lines of type containing critical text. In instances where any of the critical information was printed in a single line, leading was not measured. Average, minimum and maximum values of leading measurements are presented in Figure 14. Leading surrounding the product name tended to be larger than for the other critical elements.

The leadings surrounding expiration dating was not measurable because it was always presented in a single line.

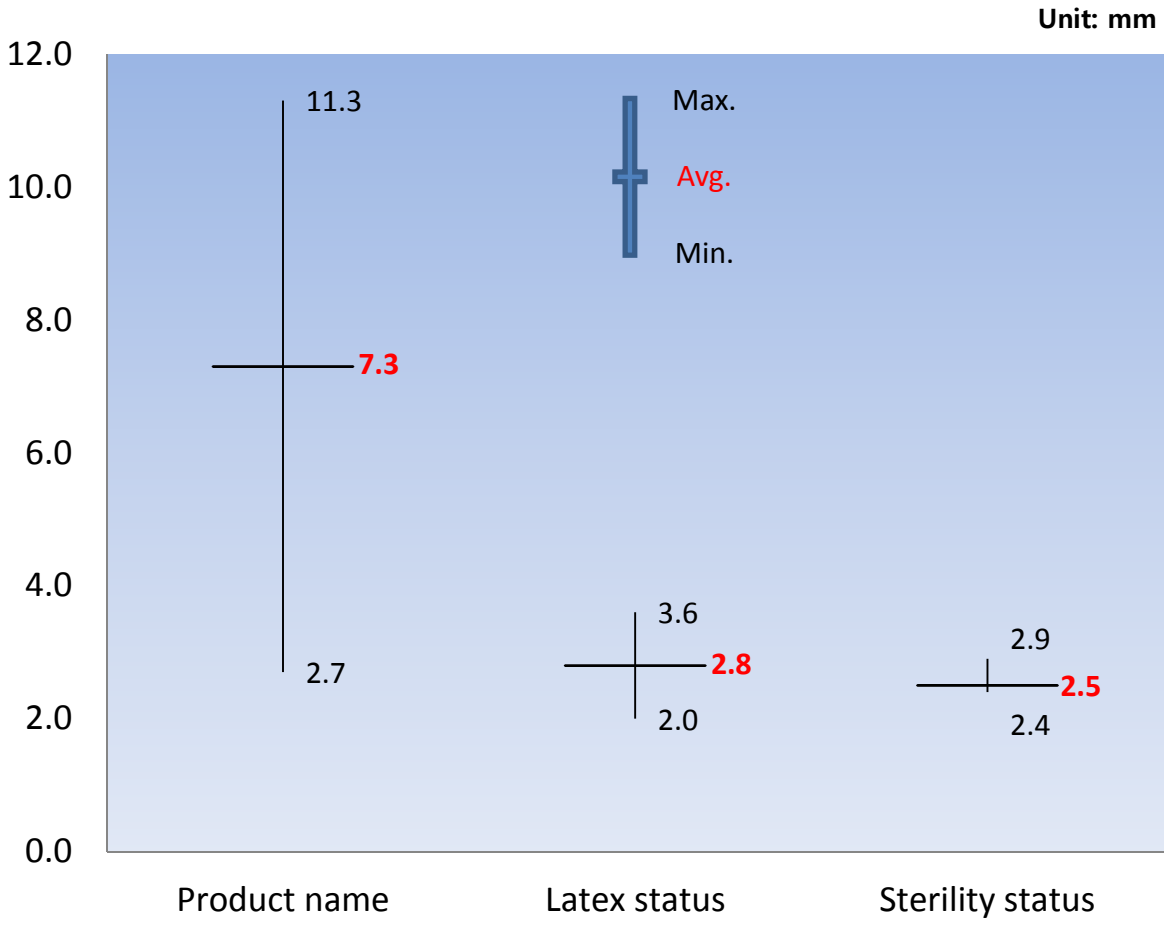


Figure 14. Leading measurement results in regard to three pieces of critical information

The x-height of text used for critical information for each of the 20 packages was measured to characterize the type size. When text was present in only capital letters, the height of the capitals was used. Average, minimum and maximum values of x-height measurements are presented in Figure 15.

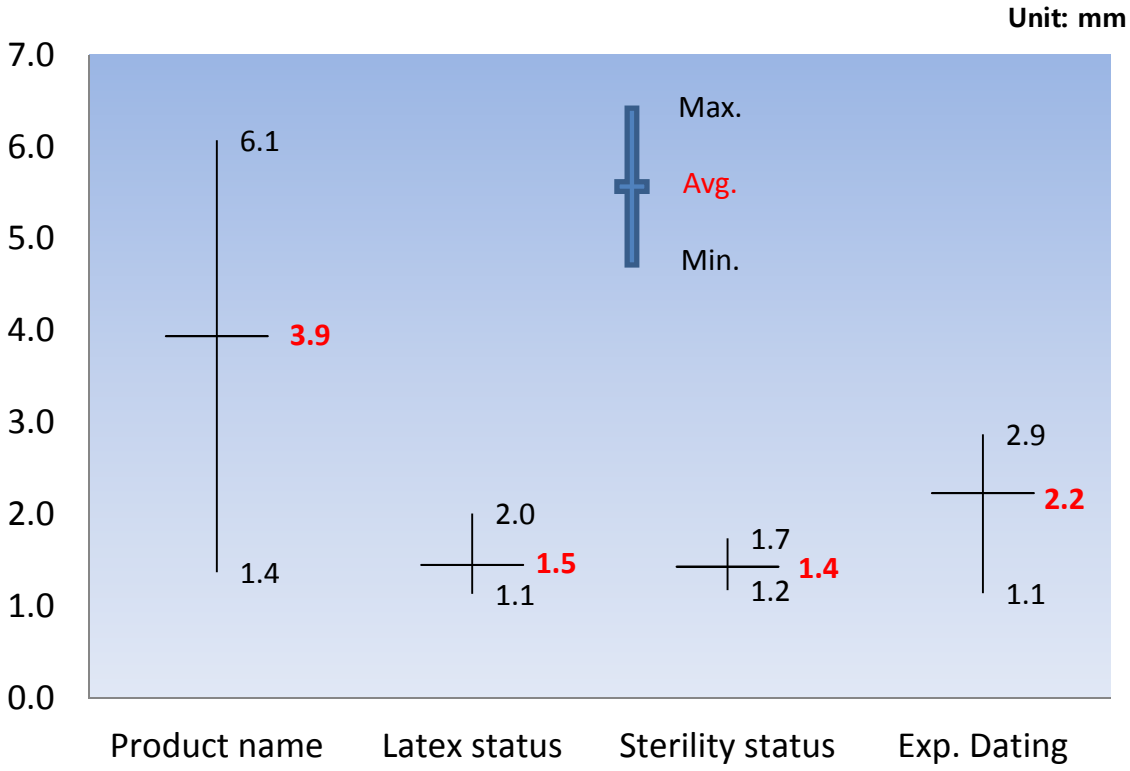
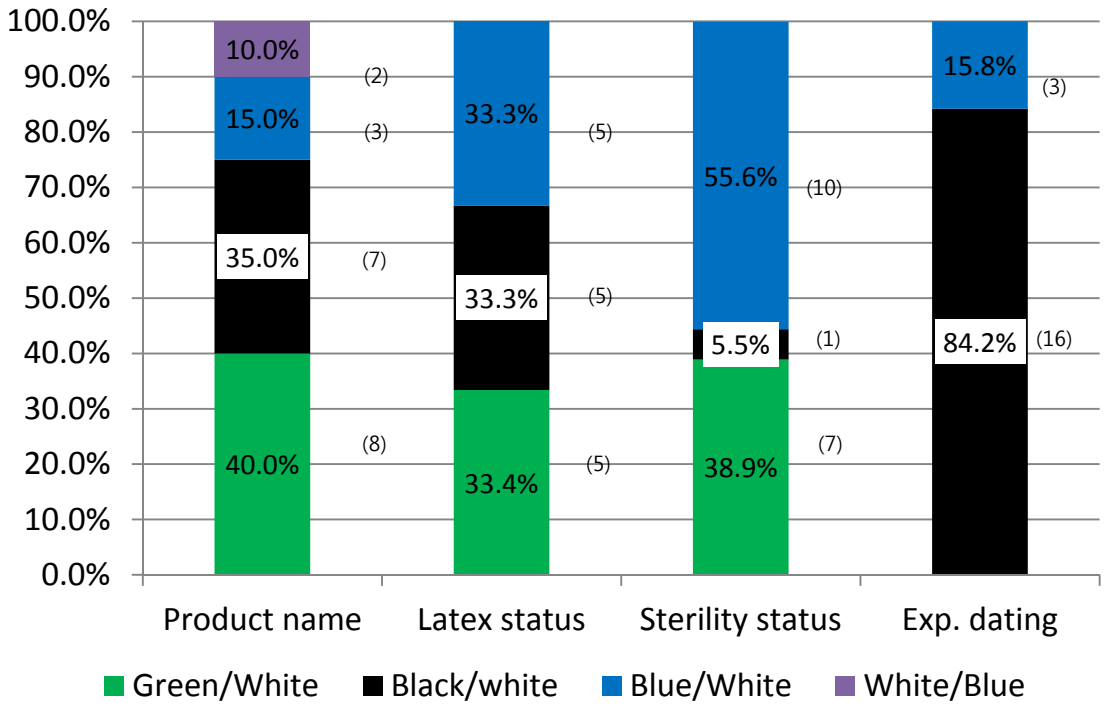


Figure 15. x-height analysis results in regard to four pieces of critical information

Text color contrast was also observed and recorded for the four pieces of critical information. Of the 20 catheters evaluated, two did not have the text associated with latex status and three had the latex status symbol only (Appendix 22). Regarding the sterility status, two out of them had the sterility status symbol only (Appendix 22). One out of them did not have its expiration date. Catheters that had symbols only and did not have critical information were not counted for percentage calculations (Appendix 22). Detailed findings of the color contrast study are presented in Figure 16.



Note) Values in parenthesis represent a number of frequencies

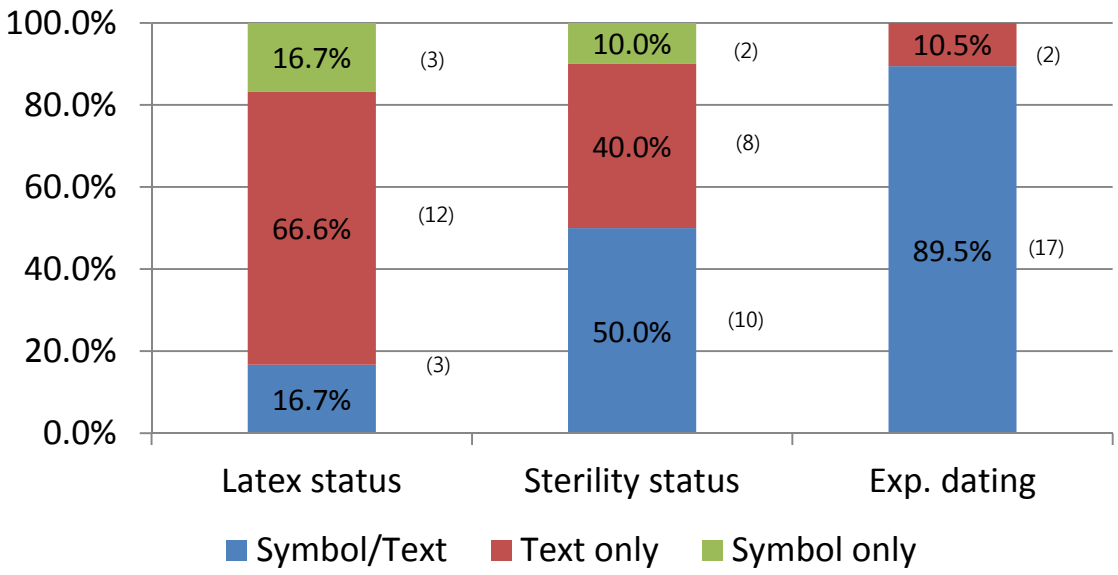
Figure 16. Findings on text color contrast in regard to four pieces of critical information

3.3.3 Symbol evaluation

Most of the symbols investigated originated from AAMI/ANSI/ISO 15223: 2007 A1: 2008 (Medical Devices – Symbols to be used with medical device labels, labeling and information to be supplied). Three latex-free symbols and one symbol related to expiration dating present are not part of the recognized standard, AAMI/ANSI/ISO 15223: 2007 A1: 2008. These non-standard symbols are presented in Figure 17.

Figure 17. Non-standard symbols found from the benchmarking study

Symbols were evaluated on whether or not they were present on a label with supplementary texts, in a text only format or in a symbol only format. Of the 20 catheters evaluated, two did not have the text or symbol associated with latex status (Appendix 26). One out of them did not have its expiration date information. Catheters that did not have critical information were not counted for percentage calculations (Appendix 26). The percentage of 'symbol/text', 'text only' and 'symbol only' for three pieces of critical information are presented in Figure 18.



Note) Values in parenthesis represent a number of frequencies

Figure 18. Symbol presence/absence findings in regard to three pieces of critical information

Average, minimum and maximum values of symbol measurements for three pieces of critical information are presented in Figure 19.

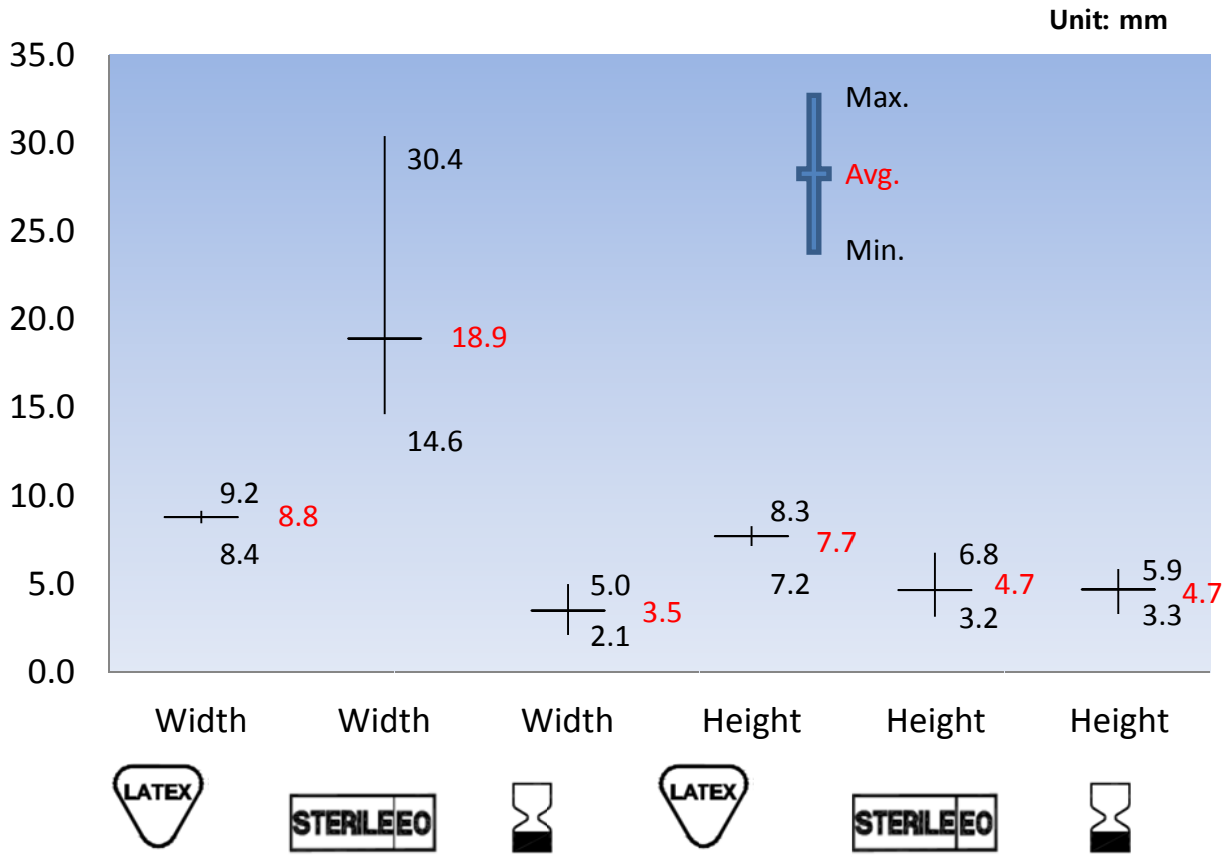
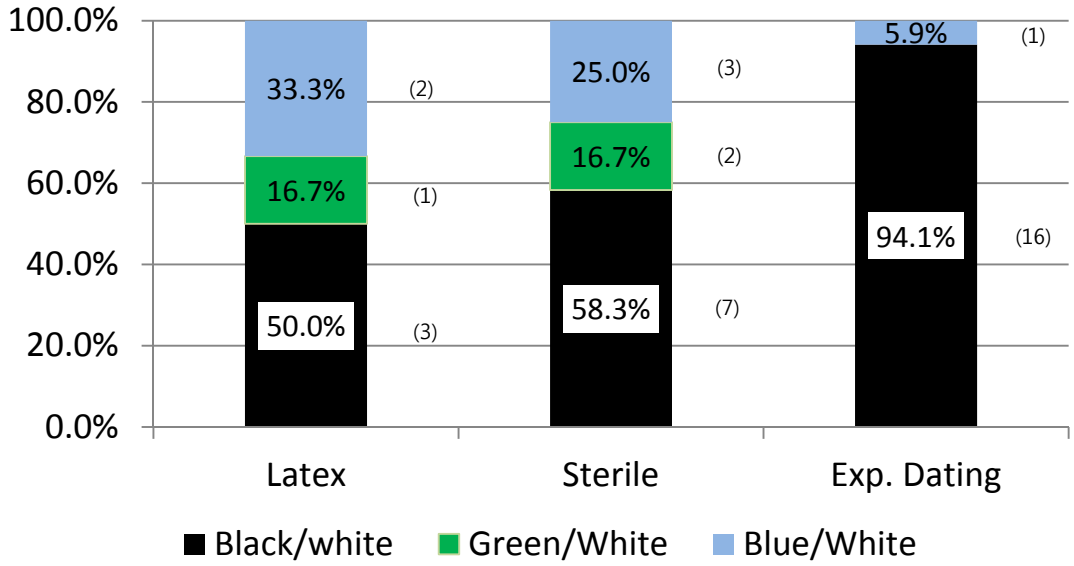


Figure 19. Symbol measurement results in regard to three pieces of critical information

The color contrasts of symbols for three pieces of critical information were evaluated. Of the 20 catheters evaluated, six had the latex status symbol, twelve the sterility status symbol and seventeen the expiration dating symbol (Appendix 24). Catheters that did not have symbols associated with each piece of critical information were not counted for percentage calculations. The detailed findings are presented in Figure 20.



Note) Values in parenthesis represent a number of frequencies

Figure 20. Findings on symbol color contrasts in regard to three pieces of critical information

3.3.4 Legibility

Ninety-nine subjects were recruited from PKG 101 and PKG 330 classes at the School of Packaging, Michigan State University. The subject group consisted of students and faculty from those two classes. Of the 99 participants, 54 were male; 45, female. The average age of participants was 20 years old (ranging from 18 to 57, median: 19). More details on the subject demographics information are presented in Figure 21.

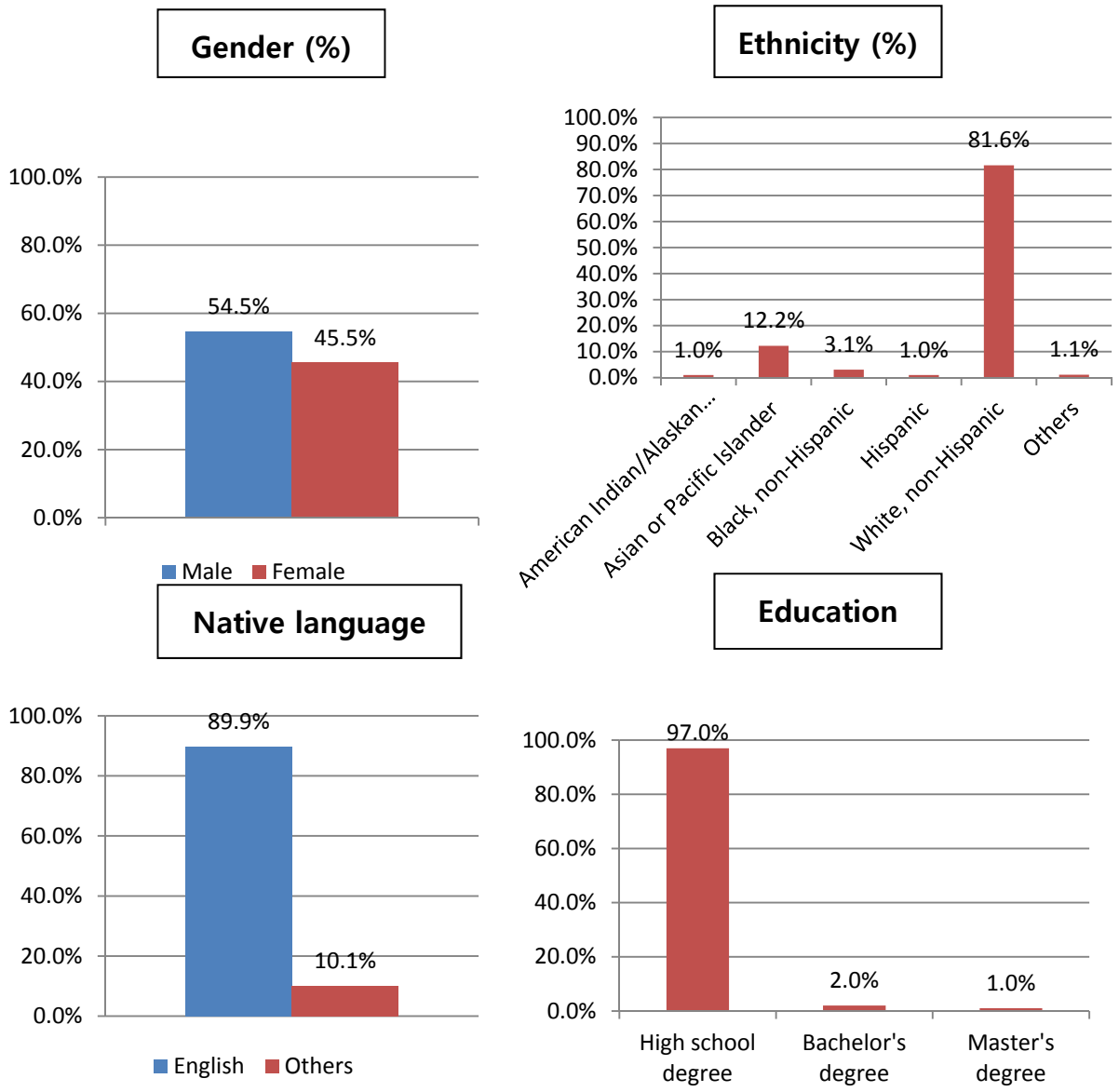


Figure 21. Demographics information of subjects for gender, ethnicity, native language and education (highest level achieved)

Three pre-tests regarding visual acuity, color blindness and health literacy were conducted prior to the legibility experiment. Details of the pre-test results are presented in Figure 22.

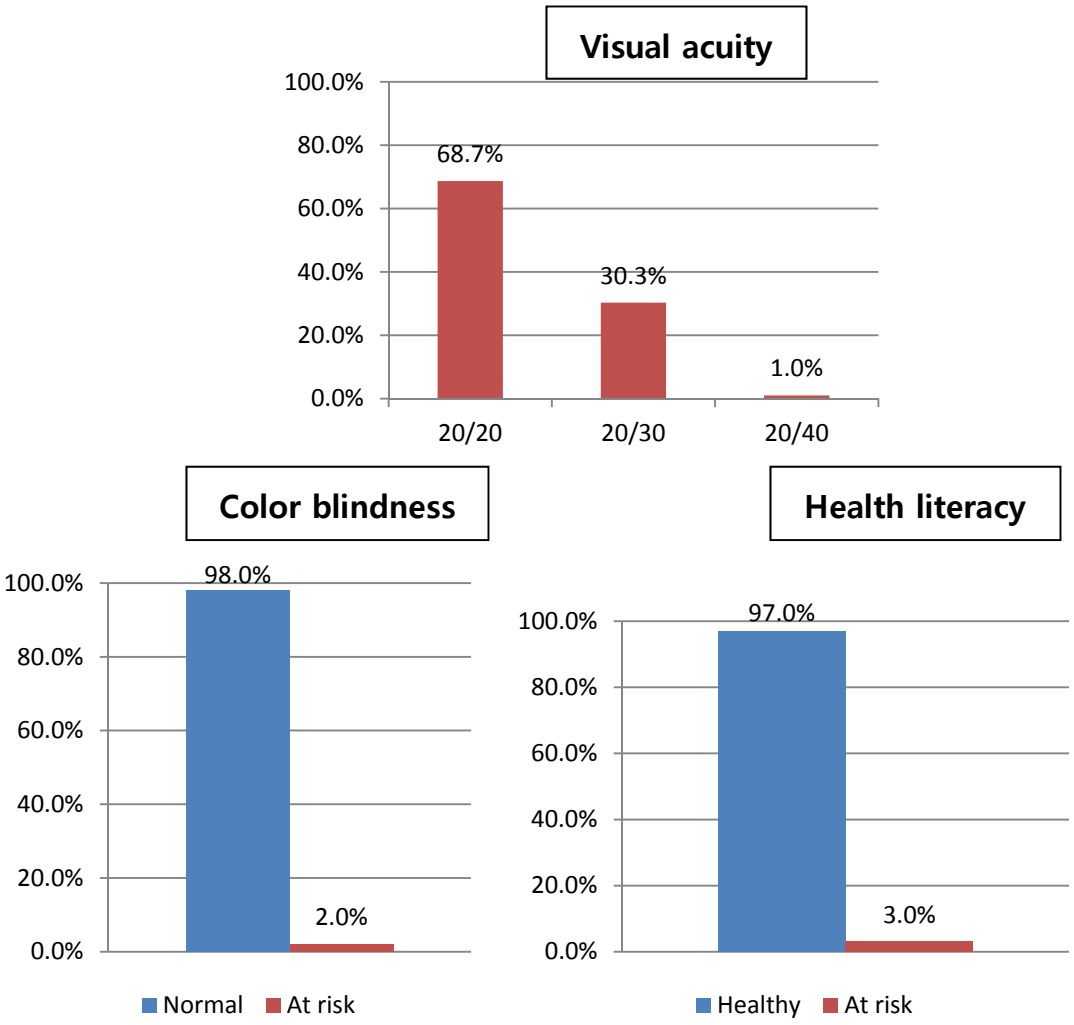


Figure 22. Subject characteristics on visual acuity, color blindness and health literacy

Legibility index readings were collected from a total of 99 subjects. The collected data were analyzed, using a general linear mixed model of the statistical software SAS 9.3 (SAS Ins., Cary, NC). The response variable (degrees of rotation) was modeled as a function of the fixed effects of labeling information (5 pieces). Gender, age, ethnicity, education level, visual acuity, health literacy, color blindness,

inside-light level and ambient light level were included in the model as explanatory covariates. Model fitting and parameter estimation was conducted using the MIXED procedure of the statistical software SAS.

The data was log-transformed to meet the normality assumption. Only age ($p=0.0006$) and inside-light level of the legibility instrument ($p<0.0001$) were retained out of all the possible covariates that were collected during the experiment, based on Type III p-values ($\alpha=0.05$).

Estimated least square means (LSM) and corresponding 95% confidence intervals (LCL: Lower Confidence Limit and UCL: Upper Confidence Limit) are reported in the original scale of a degree of rotation (Figure 23). Relevant pairwise comparisons were conducted, using Fisher's LSD.

The analysis of variance identified a significant effect of information type on the legibility readings as measured by the degrees of rotation of the polarizing filter ($p<0.0001$). Data suggest that brand name (LSM =10.3, LCL=9.5, UCL=11.2) and product name (LSM =11.1, LCL=10.3, UCL=12.1) are significantly more legible than other pieces of critical information: latex status, sterility status and expiration dating. Expiration dating (LSM =13.7, LCL=12.7, UCL=14.9) is significantly more legible that the other two pieces of critical information: latex status (LSM =16.0, LCL=14.7, UCL=17.3) and sterility status (LSM =16.0, LCL=14.8, UCL=17.4). The analyzed data suggested no evidence of a significant difference in legibility when latex status and sterility status were compared ($p=0.6544$). More details on these comparisons are presented in Figure 23.

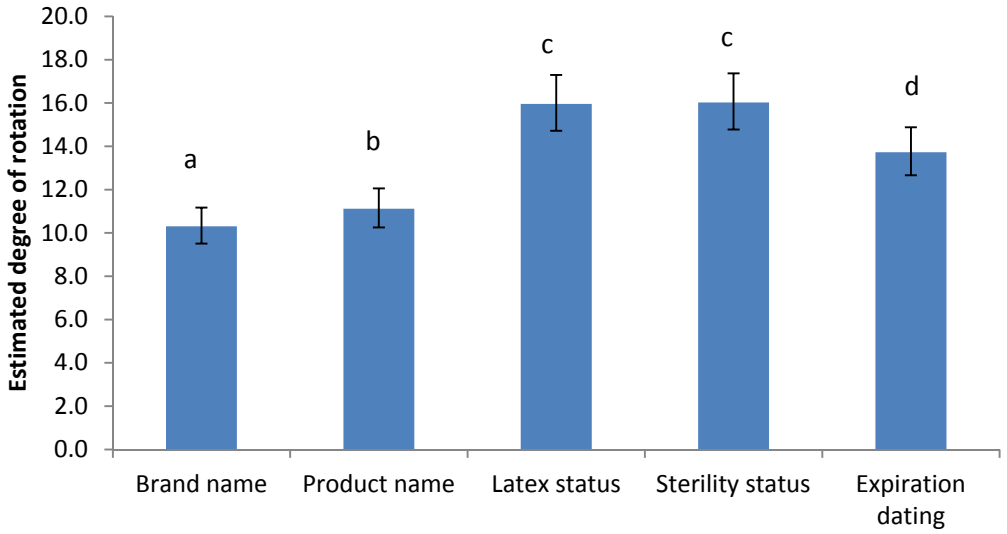


Figure 23. Estimated least square means (LSM) of degrees of rotation on legibility of the five pieces of labeling information with estimated upper and lower limits. Differing letters indicate statistical significance at α = 0.05.

3.4 Discussion and Conclusions

The purpose of this benchmarking study was to continue to explore the labeling problems identified from Cai's focus group study (Cai, 2012).

Out of 20 catheters purchased from commercial markets, not a single label contained the four pieces of critical information (product name, latex status, sterility status and expiration dating) in a single panel. This scattered information placement has the potential to be problematic when healthcare providers require critical information in a busy and/or chaotic environment. .

Results from the legibility experiment provide evidence that the three pieces of critical information (latex status, sterility status and expiration dating) were significantly less legible than brand name and product name (α=0.05). This is not surprising given

the difference in font size that was found (see Figure 15). This finding is consistent with previous work that suggests that warning and safety-related information was not as easy to read as brand name, claim statement, etc. (Bix et al., 2009).

The color contrasts on the three pieces of critical information were various and not standardized: e.g. green/white, black/white, blue/white, white/blue, etc.

This benchmarking study helps to confirm data reported by Cai (2012). Specifically, critical information was scattered, small font sizes hindered legibility, and several color contrasts were problematic. It is not unreasonable to assume that these contribute to difficulty in finding critical information on medical device labels that the same groups reported.

CHAPTER 4

DESIGN EFFECTS (BOXING, GROUPING, SYMBOL AND COLOR CODING) ON EARLY STAGES OF THE INFORMATION PROCESSING MODEL USING CHANGE DETECTION

4.1 Objective & Hypothesis

- Objective 1 – Investigate the efficacy of boxed information compared with unboxed
    - Evaluate the attentive behaviors of healthcare professionals regarding three pieces of critical information presented in a *"boxed format" vs. "unboxed format"* using a change detection methodology.
- Objective 2 – Investigate the effect of a *single location* placement of three pieces of critical information on the noticeability of said information using a change detection methodology.
- Objective 3 – Investigate the effect of *symbols (presence vs. absence)* of three pieces of critical information on noticeability using a change detection methodology.
- Objective 4 – Investigate the effect of *color coding (presence vs. absence)* of three pieces of critical information on noticeability using a change detection methodology.
- Objective 5 – Using the *symbols* identified in AAMI/ANSI/ISO 15223: 2007 A1:2008, evaluate *comprehension* using ISO 9186 – 1 2007: Graphical symbols – Test methods – Part 1: Methods for testing comprehensibility.

- **Hypothesis - It is hypothesized that a standard location and format of information deemed critical to care will attract attention more quickly in early stages of information processing.**

4.2 Methodology

4.2.1 Subjects

Healthcare professionals were recruited at the Association of Surgical Technologists (AST) conferences in Savannah, GA and Denver, CO, and using a targeted e-mail (see Appendix 12) of AST members within a 30 mile radius of Lansing, MI. The screening criteria in recruitment were:

- Have no history of seizure
- Be over 18 years of age
- Not be legally blind
- Be a healthcare professional, or a student in a healthcare field.

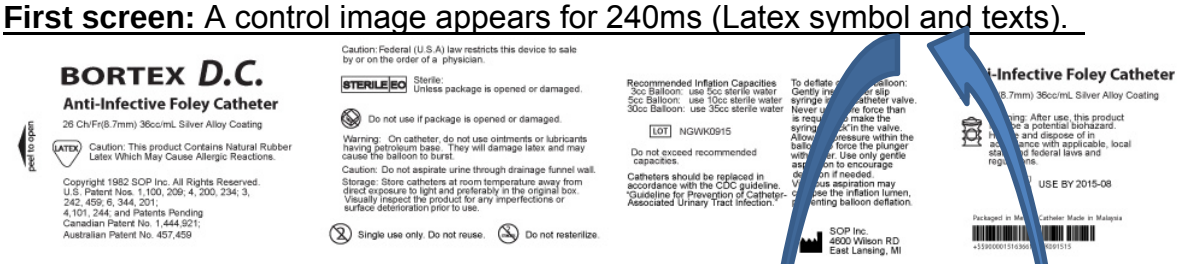
Eighty-six healthcare professionals (primarily surgical technologists and nurses) participated in two experiments: change detection to evaluate the efficacy of varied designs for critical information and symbol comprehension evaluation.

This study was conducted using procedures approved under IRB # 13-698. Prior to testing, a research consent form was provided to subjects to acquire their informed consent (see Appendix 9). Three tests were conducted to characterize participants, namely: visual acuity, color blindness and health literacy. Further, a research questionnaire was given to subjects to collect subject demographic and job-related information (see Appendix 7).

4.2.2 Equipment and Software: Change Detection

During the change detection trials ("flicker task"), subjects were comfortably seated in front of a computer screen and asked to depress the computer's space bar as soon as they noticed the "flickering portion" of an image showing on the screen. During each flicker trial, a control image (240ms) continuously alternated with the test image (240ms) that had been slightly altered with a brief, gray screen image (80ms) interleaving as shown in Figure 24. The only difference between the control and test images was the disappearance of a single piece of information on the label (for critical trials, a piece of critical information). This sequence control-blank-test-blank looped until the participant pressed the space bar, indicating that they had found the alternation, or until they timed out at 1 minute. Testing was conducted using E-Prime 2.0 (Psychology Software Tools, Inc.) and trials were randomized to mitigate any run order effects. Additionally, each trial image was divided into 4 sectors and the individual section images for all trials were randomized to mitigate any location effects (Figure 25).

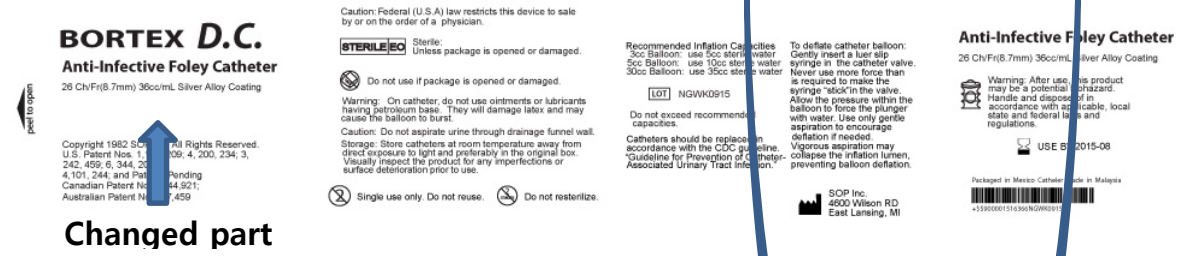
First screen: A control image appears for 240ms (Latex symbol and texts).



Section 1 *Section 2* *Section 3* *Section 4*

Second screen: A gray image appears for 80ms.

Third screen: A test image appears for 240ms (Latex symbol and texts are disappearing).



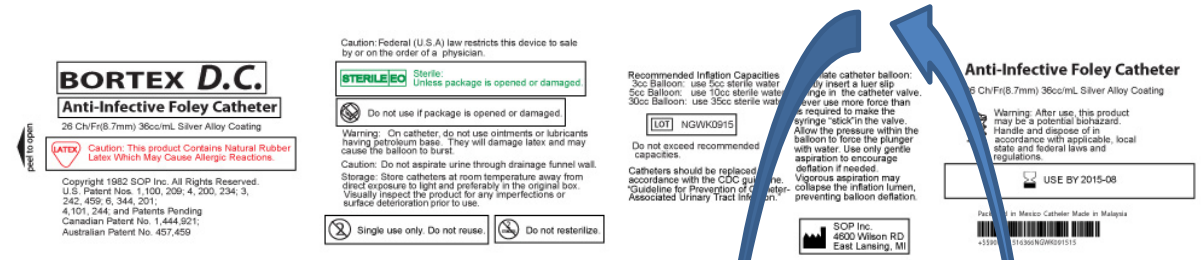
Section 1 *Section 2* *Section 3* *Section 4*

Fourth screen: A gray image for 80ms (Returning back to the control image if a subject does not press the computer's space bar).

Figure 24. Sequence of Change Detection images

Figure 24. (Cont'd)

First screen: A control image appears for 240ms (Sterile symbol and texts).

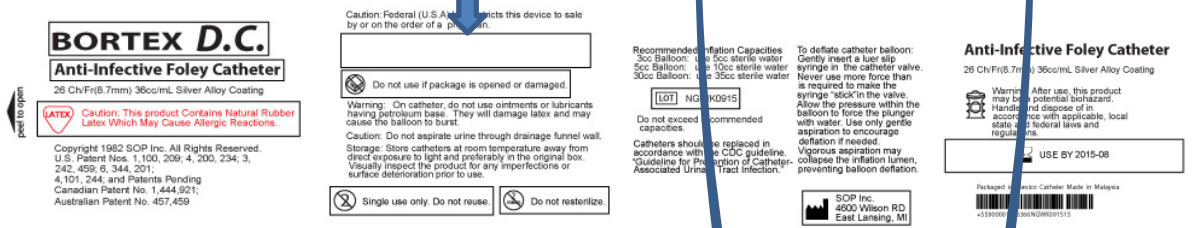


Section 1 *Section 2* *Section 3* *Section 4*

Second screen: A gray image appears for 80ms.

Third screen: A test image appears for 240ms (Sterile symbol and texts are disappearing).

Changed part

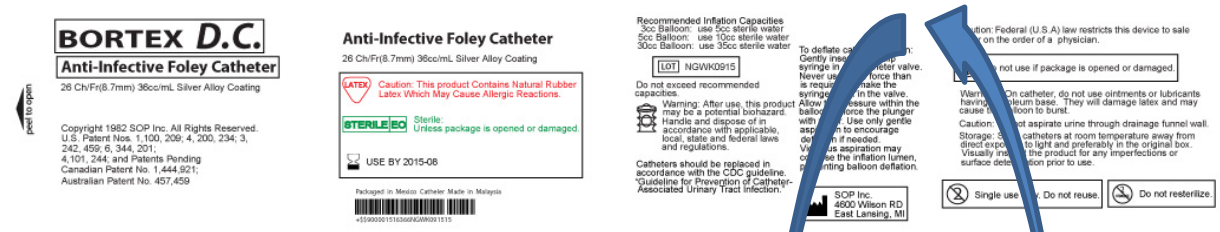


Section 1 *Section 2* *Section 3* *Section 4*

Fourth screen: A gray image for 80ms (Returning back to the control image if a subject does not press the computer's space bar).

Figure 24. (Cont'd)

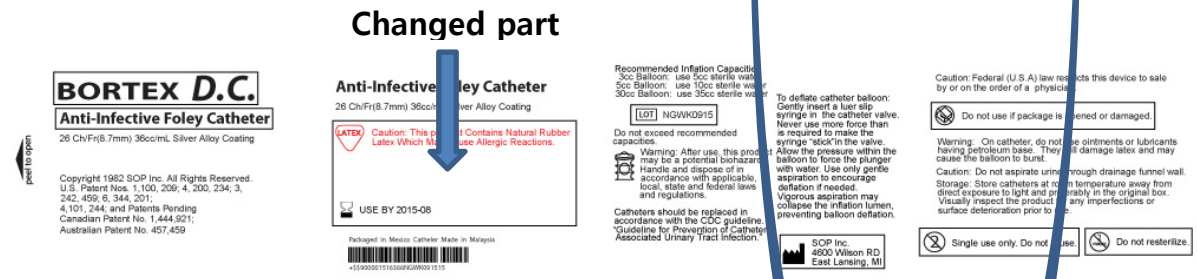
First screen: A control image appears for 240ms (Sterile symbol and texts)



Section 1 *Section 2* *Section 3* *Section 4*

Second screen: A gray image appears for 80ms.

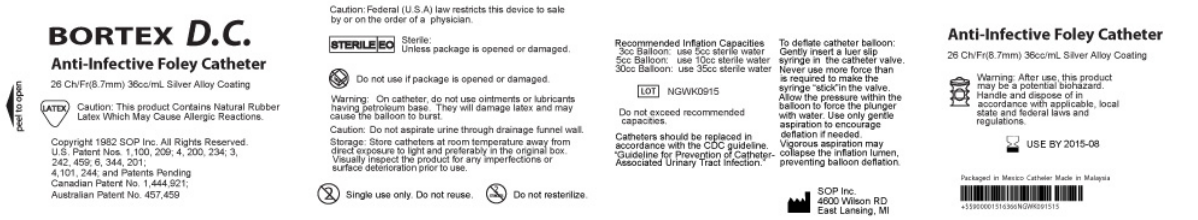
Third screen: A test image appears for 240ms (Sterile symbol and texts are disappearing).



Section 1 *Section 2* *Section 3* *Section 4*

Fourth screen: A gray image for 80ms (Returning back to the control image if a subject does not press the computer's space bar).

A label was divided into 4 section images.

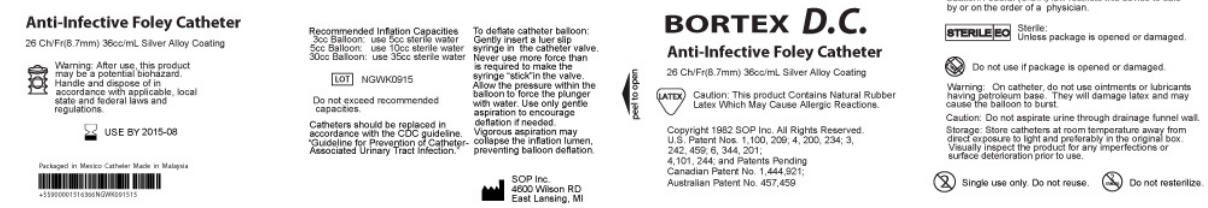


Section 1 ***Section 2*** ***Section 3*** ***Section 4***

Locations of section images were randomized per subject.

Example 1

Example 2



Example 3

Figure 25. The same label appears with sections in different locations. Location was randomized across subjects.

4.2.3 Material and Method: Efficacy of boxing, grouping, symbol and color

Trial labels were developed using Adobe Illustrator CS 3.0. Their size was 1,280 pixels wide by 768 pixels tall. Each trial label was divided into 4 sectors for randomization as explained in the previous section. Each sector image in a label was 256 pixels wide by 192 pixels tall.

Each of the design factors (Boxing, Grouping, Symbol and Color) was evaluated at two levels, present or absent. Conditions were crossed for a total of sixteen treatments (2 x 2 x 2 x 2) of interest for each piece of critical information (Table 17):

- (1-2) grouped information within a box with and without a symbol in a color-coded format,
- (3-4) grouped information unboxed with and without a symbol in a color-coded format,
- (5-6) ungrouped information within a box with and without a symbol in a color-coded format, and
- (7-8) ungrouped information, unboxed with and without a symbol in a color-coded format
- (9-10) grouped information within a box with and without a symbol in a non-color-coded format,
- (11-12) grouped information unboxed with and without a symbol in a non-color-coded format,
- (13-14) ungrouped information within a box with and without a symbol in a non-color-coded format, and
- (15-16) ungrouped information, unboxed with and without a symbol in a non-color-coded format (see Table 17).

Table 17. Experiment combinations of Change Detection	
Critical information	sterility status, latex status and expiration dating
Boxing format	boxed vs. unboxed information: 2 levels
Grouping format	grouped vs. ungrouped information: 2 levels
Symbol and Text format	symbol with text (symbol present) vs. text only without symbol (symbol absent) : 2 levels
Color coding format	color-coded vs. non-color-coded: 2 levels

Color coding consisted of color-coded and non-color-coded formats. In the color-coded format, *red (text and symbol) and white (background) colors* were used when latex information was present, *green (text and symbol) and white (background) colors,* when sterile information was present, and *black (text and symbol) and white (background) colors,* when expiration date was present (see Table 18). In the non-color-coded format, *black (text and symbol) and white (background)* colors were used for all three pieces of information (see Table 18).

Table 18. Color coding formats: Change Detection		
Critical information	**Color-coded**	**Non-color-coded**
Sterility status	 Sterile: Unless package is opened or damaged.	 Sterile: Unless package is opened or damaged.
Latex status	 Caution: This product Contains Natural Rubber Latex Which May Cause Allergic Reactions.	 Caution: This product Contains Natural Rubber Latex Which May Cause Allergic Reactions.
Expiration dating	 USE BY 2015-08*	 USE BY 2015-08

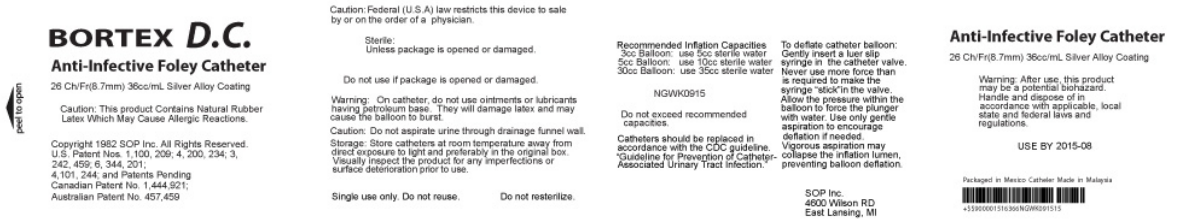
*In color coded trials of expiration date, the latex and sterility status appeared as color-coded information; expiration date (the changing element) appeared in black and white.

The sixteen treatments previously described were applied for each of three pieces of critical information (sterility status, latex status and expiration dating), for a total of 48 critical trials (16 x 3) for the change detection testing (Table 19). In addition to the 48 trials (Figures 26 and 27) where changes occurred to critical information, 48 filler trials were created (Figures 27 and 28). As such, there were 96 trials per participant; run order was randomized by subject; position of the quadrants within the label was also randomized as pilot testing suggested location effects. The details of the 96 trials are shown in Table 19.

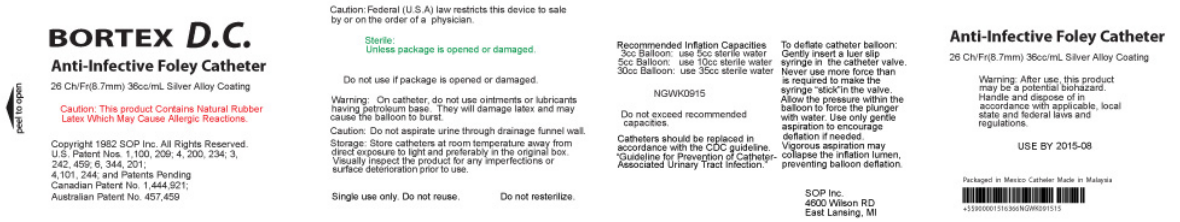
Table 19. Matrix Chart of Change Detection Trials							
Label image	**Grouping**	**Color coding**	**Label information**	**Symbol with text**		**Text only without symbol**	
				Boxed	**Unboxed**	**Boxed**	**Unboxed**
Critical information trials (Image Type A)	Ungrouped	Color-coded	Sterility status	1	2	3	4
			Latex status	5	6	7	8
			Expiration dating	9	10	11	12
		Non-color-coded	Sterility status	13	14	15	16
			Latex status	17	18	19	20
			Expiration dating	21	22	23	24
Critical information trials (Image Type B)	Grouped	Color-coded	Sterility status	25	26	27	28
			Latex status	29	30	31	32
			Expiration dating	33	34	35	36
		Non-color-coded	Sterility status	37	38	39	40
			Latex status	41	42	43	44
			Expiration dating	45	46	47	48
Dummy trials (Image Type B)	Grouped	Non-color-coded	Brand name	NA*	NA*	49	50
			Product name	NA*	NA*	51	52
			Do not reuse	53	54	55	56
			Do not resterilize	57	58	59	60
Dummy trials (Image Type A)	Ungrouped		Manufacturer	61	62	63	64
			Do not use	65	66	67	68
			Batch code	69	70	71	72
Dummy trials (Image C)	Ungrouped	Non-color-coded	Brand name	NA*	NA*	73	74
			Product name	NA*	NA*	75	76
			Do not reuse	77	78	79	80
			Do not resterilize	81	82	83	84
			Manufacturer	85	86	87	88
			Do not use	89	90	91	92
			Batch code	93	94	95	96

**Not all combinations of filler trials were tested.*

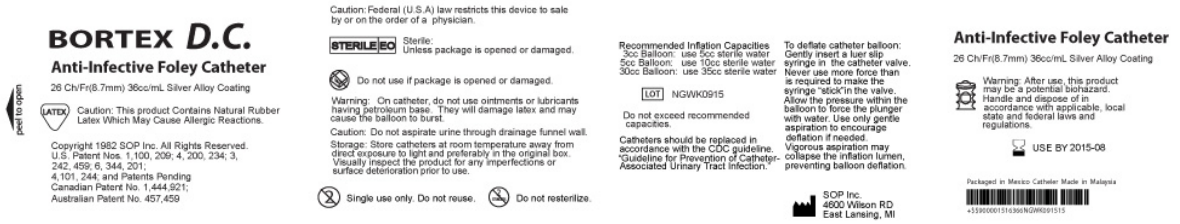
Ungrouped, Unboxed, Symbol absent and Non-color-coded conditions



Ungrouped, Unboxed, Symbol absent and Color-coded conditions



Ungrouped, Unboxed, Symbol present and Non-color-coded conditions



Ungrouped, Unboxed, Symbol present and Color-coded conditions

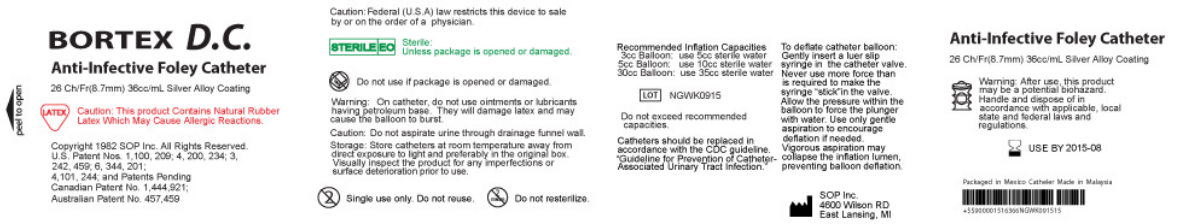
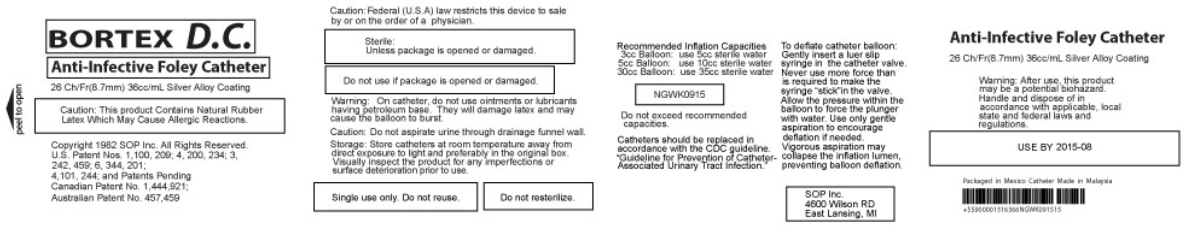


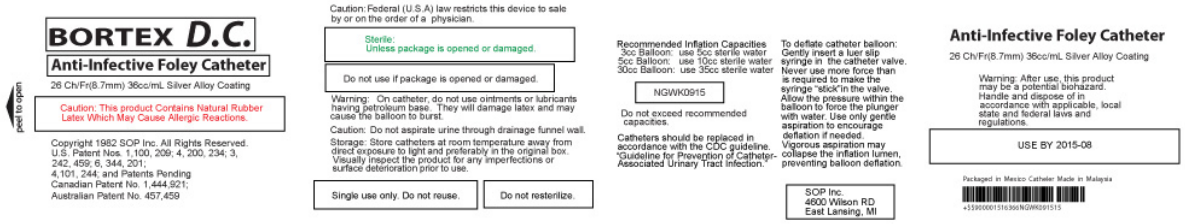
Figure 26. Change Detection trials: Image Type A

Figure 26. (Cont'd)

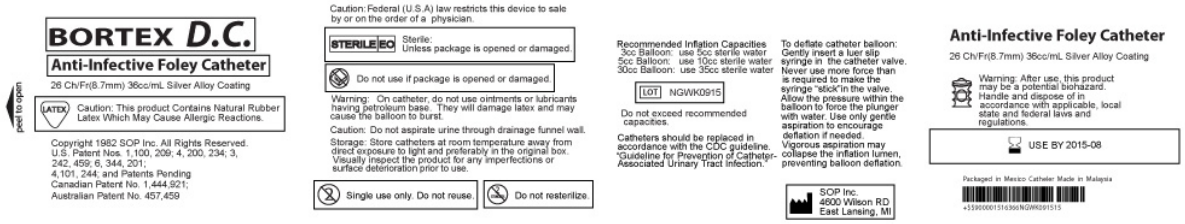
Ungrouped, Boxed, Symbol absent and Non-colored conditions



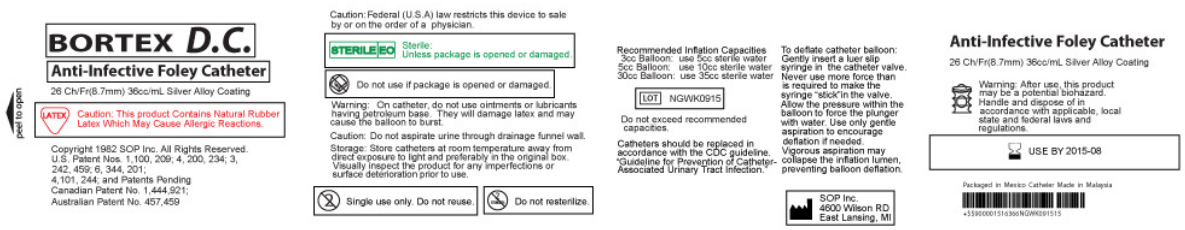
Ungrouped, Boxed, Symbol absent and Color-coded conditions



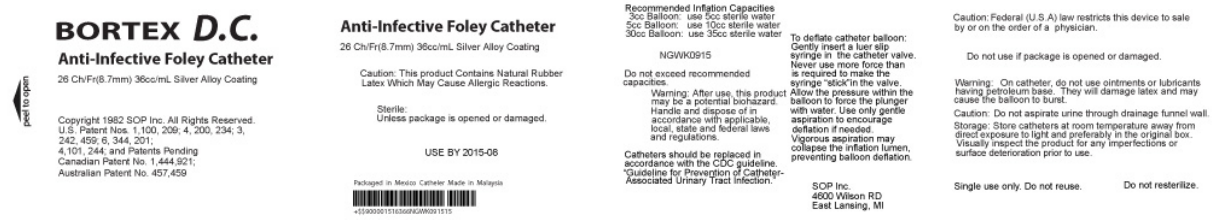
Ungrouped, Boxed, Symbol present and Non-color-coded conditions



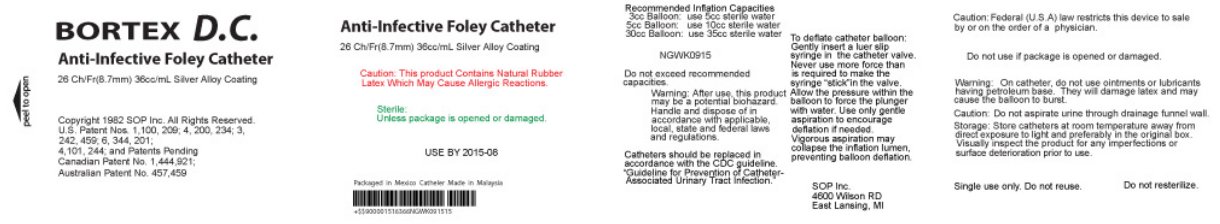
Ungrouped, Boxed, Symbol present and Color-coded conditions



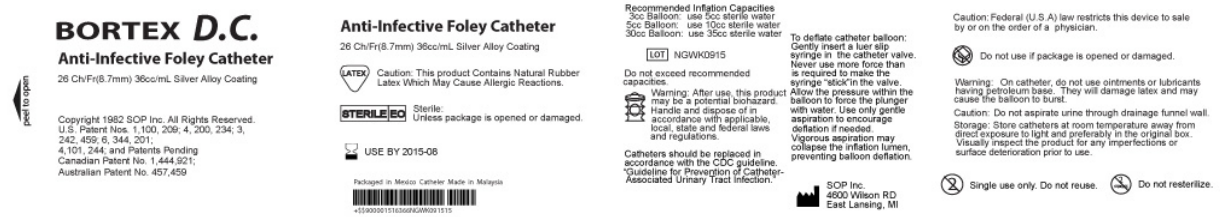
Grouped, Unboxed, Symbol absent and Non-color-coded conditions



Grouped, Unboxed, Symbol absent and Color-coded conditions



Grouped, Unboxed, Symbol present and Non-color-coded conditions



Grouped, Unboxed, Symbol present and Color-coded conditions

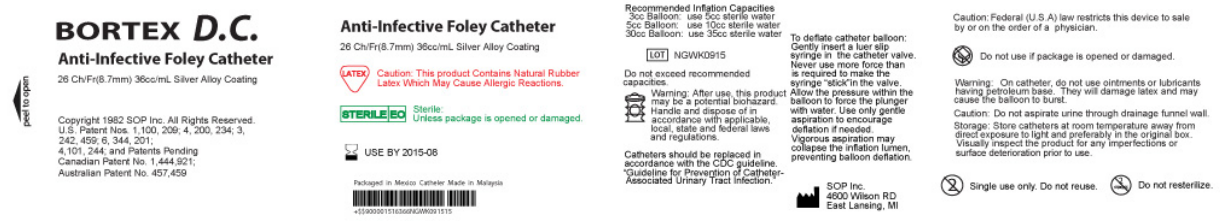
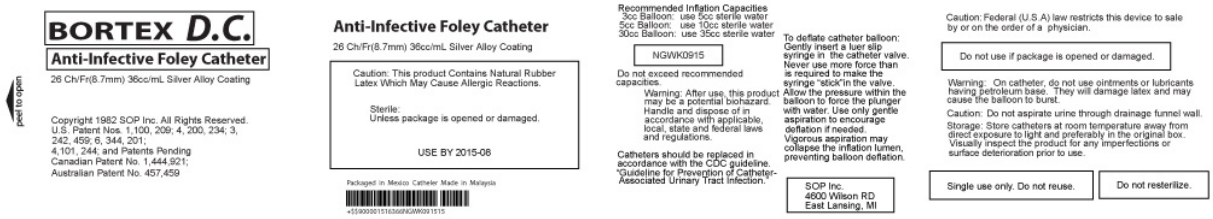


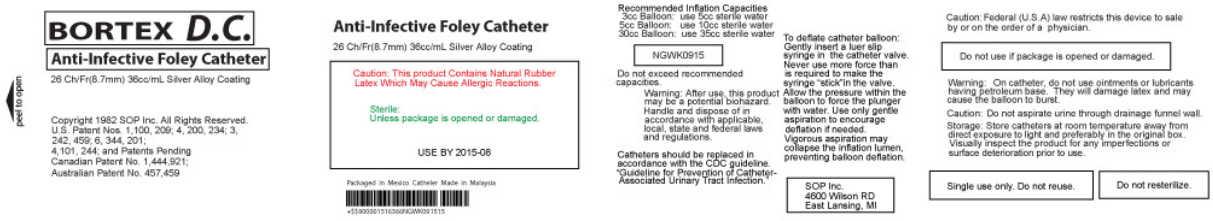
Figure 27. Change Detection trials: Image Type B

Figure 27. (Cont'd)

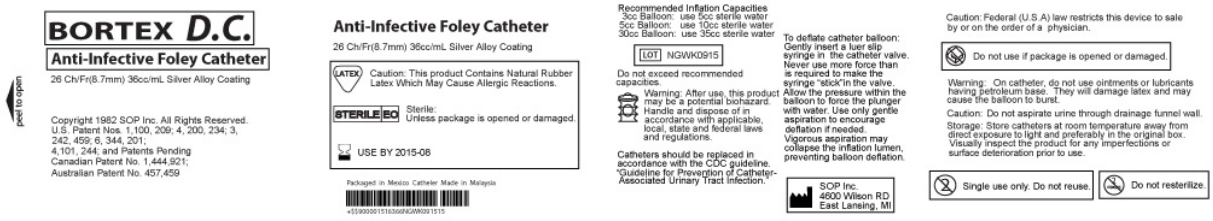
Grouped, Boxed, Symbol absent and Non-color-coded conditions



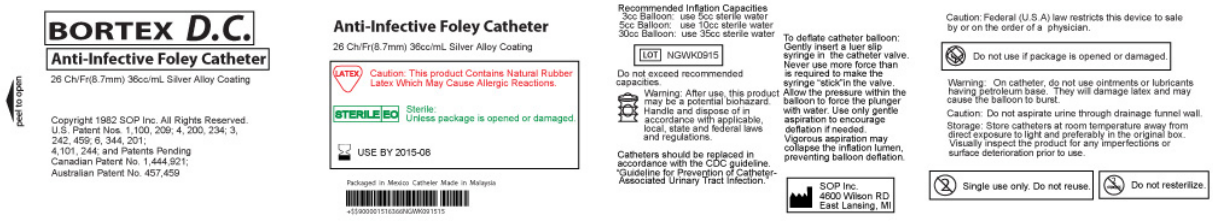
Grouped, Boxed, Symbol absent and Color-coded conditions



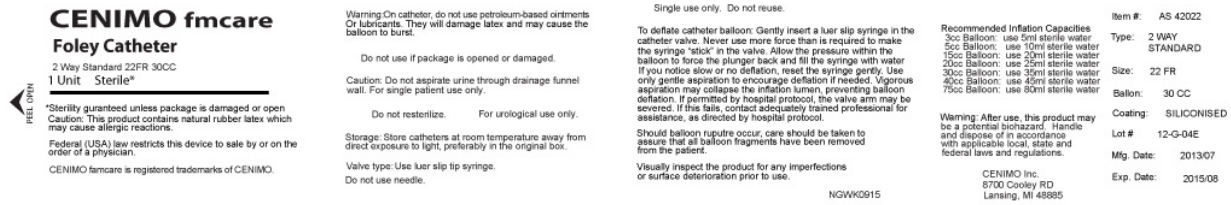
Grouped, Boxed, Symbol present and Non-color-coded conditions



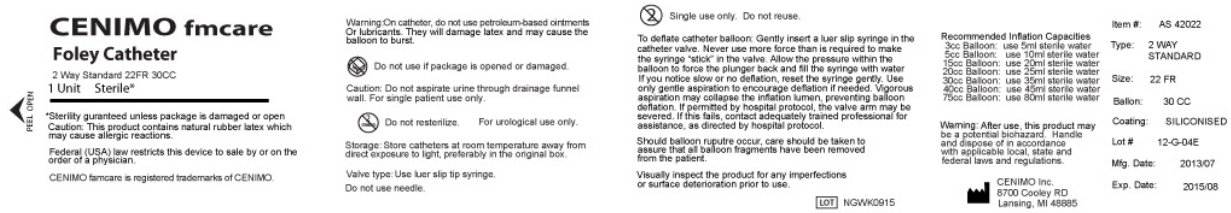
Grouped, Boxed, Symbol present and Color-coded conditions



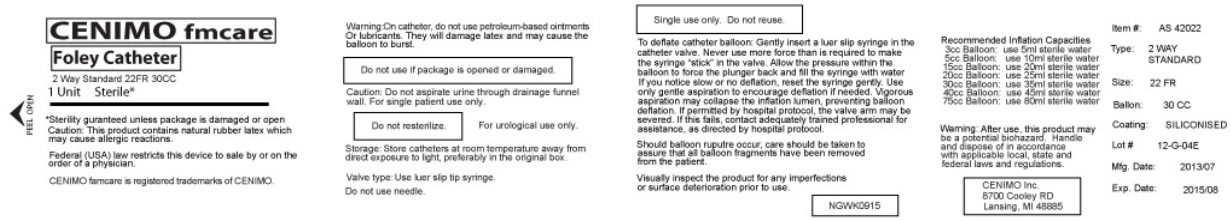
Ungrouped, Unboxed, Symbol absent and non-color-coded conditions



Ungrouped, Unboxed, Symbol present and non-color-coded conditions



Ungrouped, Boxed, Symbol absent and Non-color-coded conditions



Ungrouped, Boxed, Symbol present and Non-color-coded conditions

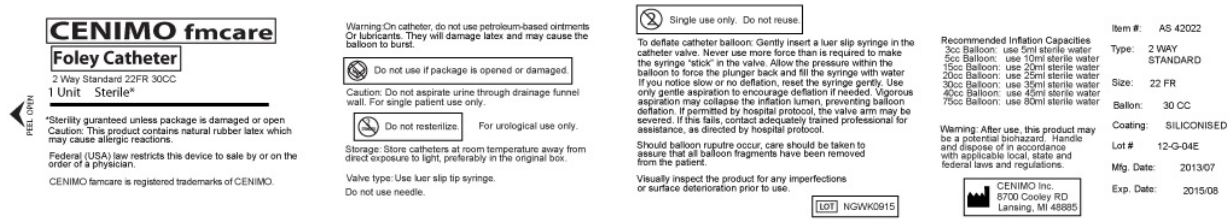


Figure 28. Change Detection trials: Image Type C

4.2.4 Materials and Method: Comprehension of symbols

Symbols for warnings, cautions, etc. are commonly used for pharmaceutical and medical device products to reduce or eliminate potential risks. It is very important that product users comprehend the correct meaning of symbols intended to convey important information regarding many medical devices.

Comprehension testing quantifies the degree of understanding of symbols by the target group and intends to answer the questions: “What do you think this means?” or “What action would you take in response to this symbol?” (ISO 9186-1, 2007).

4.2.4.1 Stimulus Materials

A set of printed test sheets was prepared with 41 graphical symbols within a square not less than 28 mm x 28 mm such that the graphical symbol filled the square (ISO 9186-1 2007). The 38 symbols, standardized and defined by AAMI/ANSI/ISO 15223: 2007 A1: 2008 were included in the comprehension test form. Along with those 38 symbols, three latex-free symbols that were identified from the previous benchmarking study were tested (Experiment 1 – see Figure 17). The set of printed test sheets was given to subjects with the following instruction (see Appendix 6):

> *“This study is intended to evaluate your comprehension level of medical device symbols used for commercially available medical devices.”*

4.2.4.2 Procedure

Participants were instructed to record their answer to the question: “What do you think this symbol means?” In addition, they were told to write the response “Don’t know” if they were unable to assign a meaning to the symbol. There was no time limit for them to fill out the symbol comprehension form.

4.2.4.3 Categorization

According to ISO 9186-1:2007, subject responses were categorized as below:

- *1: Correct,*
- *2a: Wrong, 2b: Wrong and the response given is the opposite of the intended meaning*
- *3: The response given is "Don't know"*
- *4: No response is given.*

All the responses regarding symbol meaning were coded in an excel spreadsheet. Three judges reviewed categorized codes, and in-depth discussion among three judges was conducted to come up with consensus on unmatched response codes. The responses in category 1 were considered a correct answer. Responses from categories 2 to 4 were tallied as incorrect. Percentage by category code was calculated for each symbol by dividing the number responses in a category by the total number of responses for that symbol response. The criterion of 85% described in ANSI Z535.3 was applied to evaluate participants' comprehension level (ANSI Z535. 1-5 2011, & Liu et al., 2005). Symbols which generate more than an 85% response rate in category 1 were considered as having an acceptable comprehension level; conservatively, we defined this as having an Upper Confidence Limit (UCL) that exceeded the 85% value.

4.3 Results

4.3.1 Subject demographics

Eighty-six healthcare professionals were recruited at the Association of Surgical Technologists (AST) conferences in Savannah, GA and Denver, CO, and using a targeted e-mail (see Appendix 12) of AST members within a 30 mile radius of Lansing, MI. The average age of participants was 44 years old (ranging from 18 to 66, median: 47). Figure 29 provides information regarding the age of the test population.

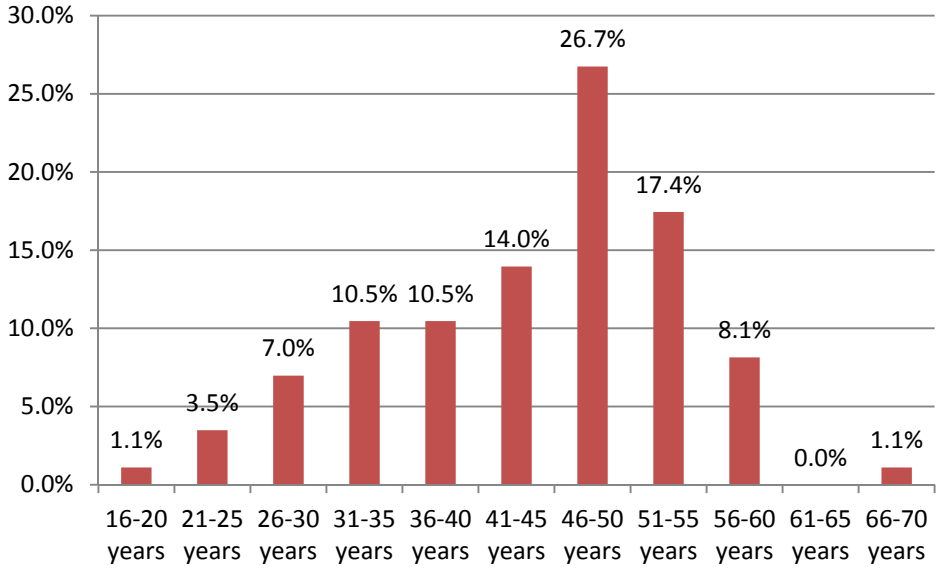


Figure 29. Age of participants

Of the 86 participants, 17 were male; 69 female. Eighty-four participants were native speakers of English. More details on the demographics are presented in Figure 30.

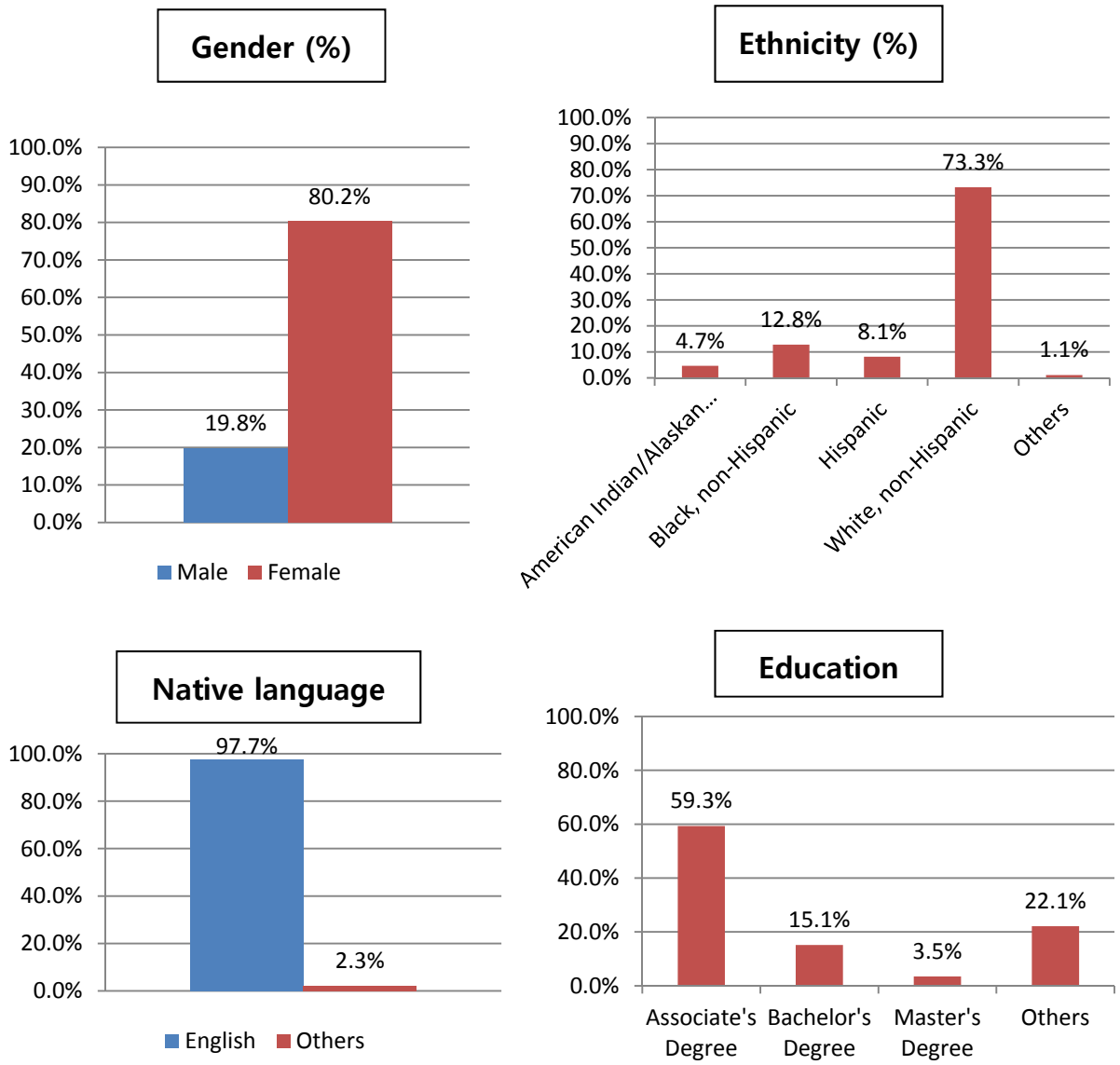


Figure 30. Demographics information (%) of participants on gender, ethnicity, native language and education (highest level achieved)

The three pre-tests regarding visual acuity, color blindness and health literacy were conducted prior to the change detection and symbol comprehension experiments. The details of the pre-test results are presented in Figure 31.

Figure 31. Subject characteristics (%) for visual acuity, color blindness and health literacy

4.3.2 Descriptive statistics on questionnaire evaluation

4.3.2.1 Years of experience

On average, the subject population had 20 years of experience (ranging from 1

to 51, median: 22). Figure 32 characterizes the subject population with regard to years of experience.

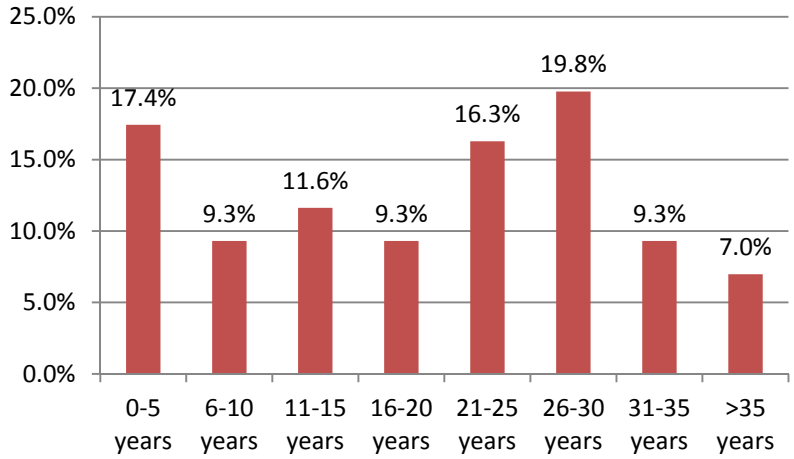


Figure 32. Experience in years

4.3.2.2 Employment settings

Healthcare providers work in diverse care settings. Figure 33 provides an indication of the frequency of employment setting as self-reported by participants.

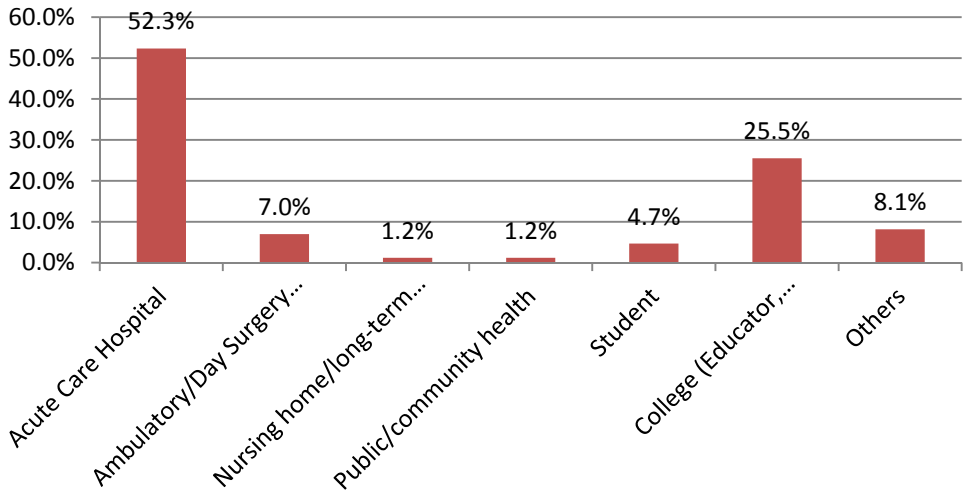


Figure 33. Employment settings of participants (%)

4.3.2.3 Position & role

Figure 34 depicts the frequencies with which participants reported their role in healthcare.

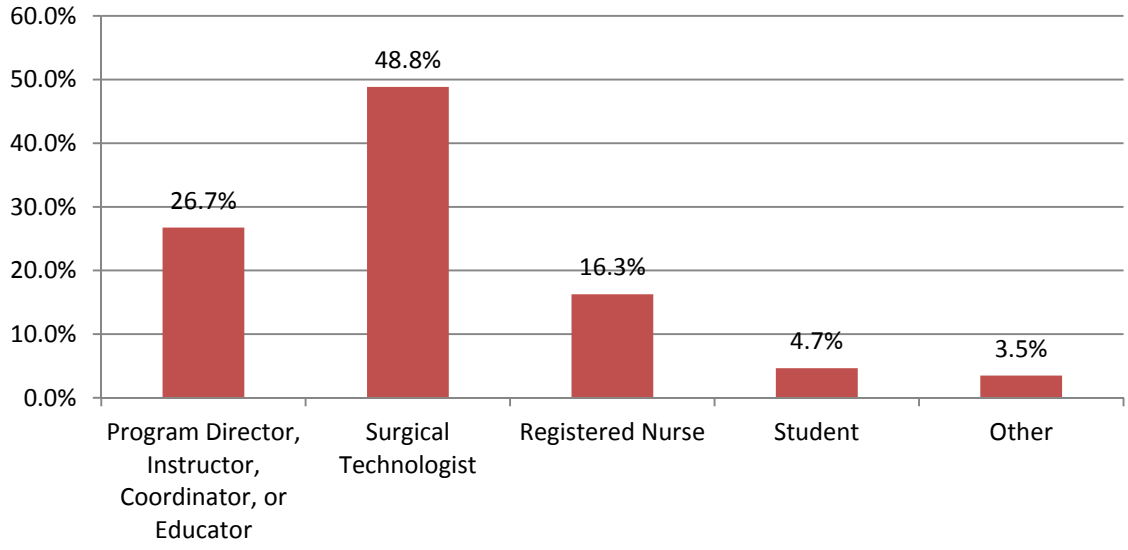


Figure 34. Position & role of participants (%)

4.3.2.4 Critical pieces of labeling information

Participants were asked to report the information from medical device labeling they deemed to be most important (see Survey - Appendix 7). Participants' responses were ranked from 1st (most important) to 4th (least important) items, and were categorized into 14 response groups (Appendix 14). The total frequencies of the top five responses, and their median and mode are presented in Table 20.

Table 20. Critical pieces of labeling information with top 5 out of 14 response groups					
	Expiration dating	Latex status	Sterility status	Product name	Use instructions
1 (Most important)	31	19	11	13	1
2	27	15	19	6	9
3	14	16	18	14	7
4 (Least important)	7	12	11	11	7
Total Frequency of Participant Responses	79	62	59	44	24
Median of Ranking	2	2	2	3	3
Mode of Ranking	1	1	2	3	2

4.3.2.5 Critical labeling problems

Participants were asked to write labeling problems on a response sheet (see Survey - Appendix 7). Responses were ranked from 1st (most problematic) to 4th (least problematic) items in this category, and grouped into 10 response categories (Appendix 15). The total frequencies of the top five response groups, and their median and mode are presented in Table 21.

Table 21. Critical labeling problems with top 5 out of 10 response groups					
Ranking	Small font size	No standard location for critical information	Labeling designs not standardized	No color coding	No color contrast
1 (Most problematic)	44	18	8	5	7
2	21	21	11	14	9
3	6	15	20	11	9
4 (Least problematic)	4	4	10	4	4
Total Frequency of Participant Responses	75	58	49	34	29
Median Ranking	1	2	3	2	2
Mode Ranking	1	2	3	2	2,3

4.3.2.6 Medical errors due to labeling issues

Participants were asked to report medical errors that they experienced due to labeling issues (see Survey - Appendix 7). Responses were categorized into 6 groups. Their total frequencies are presented in Table 22.

Table 22. Medical errors participants experienced due to labeling issues	
Response groups	**Total frequencies**
Wrong product/size opening or use	37
Expired product opening or use	30
Latex-containing product opening or use to latex-allergy patients	21
Incorrect dosage	11
Unsterile product opening or use	9
Other medical errors	12

4.3.2.7 Recommendations for labeling designs

Participants were asked to make suggestions regarding the resolution of

labeling problems (see Survey - Appendix 7). Suggestions were then categorized into 8 response groups. Response frequencies are summarized in Table 23.

Table 23. Suggested recommendations to resolve labeling problems

Response groups	Total frequencies
Bigger or bolder font size	57
Color coding	44
Standard location for labeling information	43
Standardization for labeling designs	29
Highlighted critical information	14
Clear color contrast	12
Standardized symbols	4
Others	19

4.3.3 Statistical analysis on Change Detection

Two response variables were obtained for this experiment from the EPrime® software for each change detection trial:

- A binary variable: Successful detection of change (Yes/No) prior to timing out at 60 seconds
- A continuous variable: Time to successful change detection prior to timing out at 60 seconds.

4.3.3.1 Binary Variable – Change Detected (Yes/No)

A generalized linear mixed model was fitted to this binary variable - change detected (yes/no or timeout at 60 seconds) using a logit-link function to model the probability of change detection (in %). Only critical trials were analyzed i.e. design changes in three pieces of critical information. Linear predictors in the model were four design factors (grouped vs. ungrouped + boxed vs. unboxed + symbol presence vs.

symbol absence + color-coded vs. non-color-coded), and all possible 2-way, 3-way and 4-way interactions were analyzed.

None of the demographic covariates was retained in the final model since there was no significant effect of those covariates, based on their Type III p values (α=0.05).

The model was fitted using the GLIMMIX procedure of SAS 9.3 (SAS Ins., Cary, NC). Relevant pair-wise comparisons were conducted using Fisher's LSD.

A total of 4,128 trials (86 subjects x 48 trials) were analyzed as part of the change detection experiment. In 98.9% of the total trials, participants correctly identified the location of change prior to timing out; 1.1% of trials resulted in incorrect identification of location.

Although there was evidence of a main effect of Grouping (p=0.0294) and Color (p=0.0499) on the probability of successful detection, these results were not practically significant because of the high rates of successful detection, regardless of treatment (e.g. grouped vs. ungrouped, and color-coded vs. non-color-coded) (Figure 35 and 36). No 2-way, 3-way and 4-way interaction terms were significant statistically.

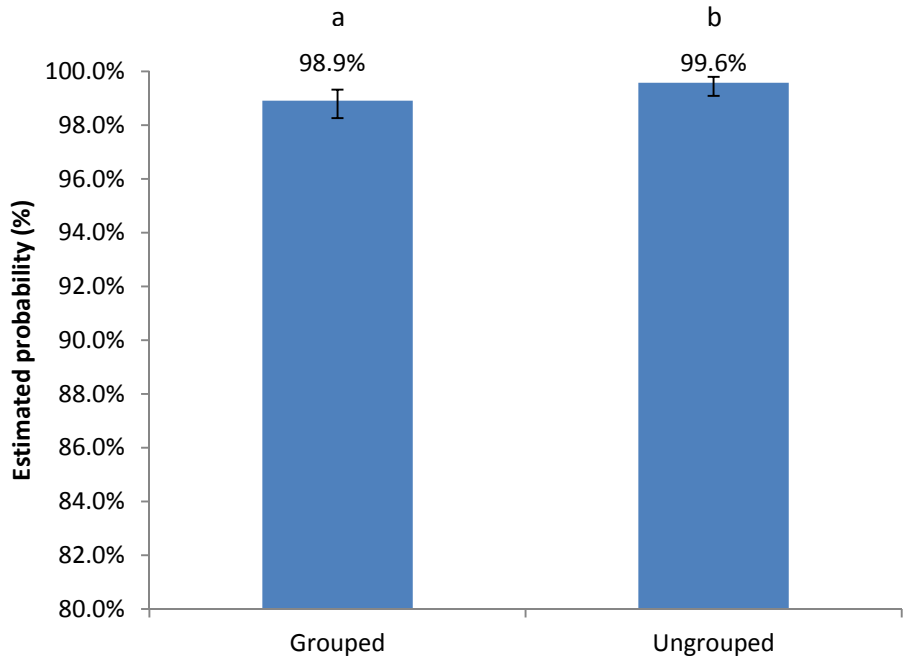


Figure 35. The effect of 'Grouping' on the probability of successful change detection: Estimated least square means (LSM) with estimated upper and lower limits. Differing letters indicate statistical significance at α=0.05.

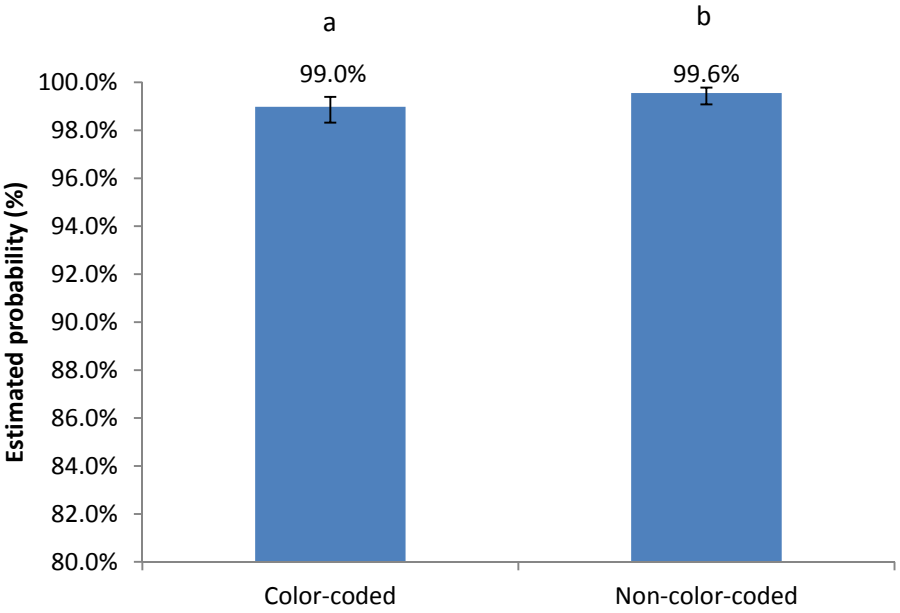


Figure 36. The effect of 'Color' on the probability of successful change detection: Estimated least square means (LSM) with estimated upper and lower limits. Differing letters indicate statistical significance at α=0.05.

4.3.3.2 Continuous Variable – Time to detect change (milliseconds)

For critical changes that were successfully detected prior to timing out at 60 seconds, a second variable, "time to detect change," was recorded in milliseconds. Gender, age, ethnicity, education level, visual acuity, health literacy, color blindness, native languages, and change location were included in the model as explanatory covariates. In order to meet necessary model assumptions, values were expressed on a log scale. Similar to the analysis for the previous variable, linear predictors in this model were the four design factors (grouped vs. ungrouped + boxed vs. unboxed + symbol presence vs. symbol absence + color-coded vs. non-color-coded), and all possible 2-way, 3-way and 4-way interactions were analyzed.

Gender, age and ethnicity were retained in the final model, based on their Type III p values (α=0.05). Change location, which was randomized in each trial by the EPrime® Software, showed a significant effect on time to successful change detection, and as such, was included as a random variable in the final model, based on its Type III p values (α=0.05).

The model was fitted using the Mixed procedure of SAS 9.3 (SAS Ins., Cary, NC). Estimated least square means (LSM) and corresponding 95% confidence intervals (LCL=Lower Confidence Limit and UCL=Upper Confidence Limit) were reported in the original millisecond scale. Relevant pairwise comparisons were conducted using Fisher's LSD.

There was evidence for a main effect of three design factors on the 'time to detect change' response: Boxing ($p<0.0001$), Symbol ($p=0.0002$) and Color ($p<0.0001$). Several 2-way interaction terms showed a significant effect on the response time

variable: ‘Grouping by boxing’ ($p<0.001$), ‘Grouping by symbol presence’ ($p=0.0253$), ‘Grouping by color’ ($p=0.0015$), ‘Boxing by color’ ($p=0.0003$), and ‘Symbol by color’ ($p=0.0028$). In addition, there was a significant effect of one 3-way interaction term, ‘Boxing by symbol by color’ ($p=0.0323$). Significant two-way interaction terms which are not included in the significant 3-way interaction term are reported below.

4.3.3.2.1 Significant 2-way interaction terms: Grouping x Boxing

This statistical analysis suggested that the time to detect changes depended on both the Grouping and Boxing designs. When designs were boxed changes took significantly less time to detect when compared to their unboxed counterpart in the grouped format ($p=0.0086$). This positive effect of boxing also took place in the ungrouped format ($p<0.0001$, Figure 37). Specifically, changes were successfully detected faster in the boxed, ungrouped condition (LSM=1740.2ms, LCL=1558.5ms, UCL=1943.1ms), when compared with the boxed, grouped condition (LSM=1925.8ms, LCL=1724.2ms, UCL=2150.3ms). By contrast, the grouped, unboxed condition (LSM=2051.6ms, LCL=1837.0ms , UCL=2290.9ms) outperformed the ungrouped, unboxed condition (LSM=2268.8ms, LCL=2031.4ms, UCL=2533.4ms, relatively; Figure 37)

This is likely because the use of the box triggered bottom-up attention response. The ungrouped, boxed condition likely triggered a search behavior in which participants rapidly moved to a series of small boxed targets (in close proximity to the information changing), quickly reaching the information that was changing. In the unboxed condition, no such benefit was present.

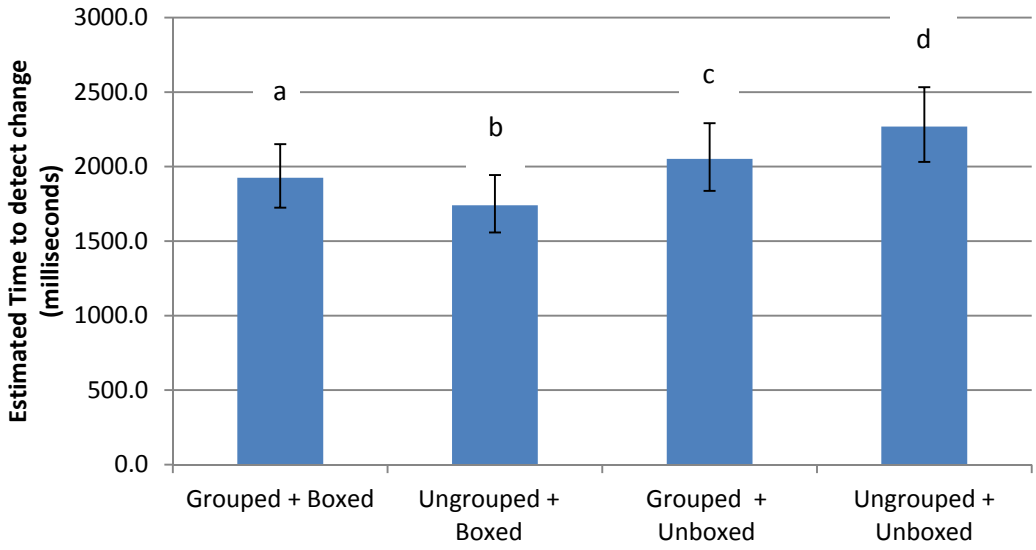


Figure 37. The effect of 'Grouping' and 'Boxing' formats on Time to detect change: Estimated least square means (LSM) with estimated upper and lower limits. Differing letters indicate statistical significance at α=0.05.

4.3.3.2.2 Significant 2-way interaction terms: Color x Grouping

The time to detect changes also depended on both Color and Grouping. Participants took less time to detect change when designs were color-coded as compared to their non-color-coded counterparts in the grouped format ($p<0.0001$). This positive effect of color also took place in the ungrouped format ($p<0.0001$, Figure 38). When non-color-coded, the ungrouped condition outperformed the grouped condition (LSM=2140.9ms, LCL=1917.3ms, UCL=2391.1ms vs. LSM=2260.5ms, LCL=2024.0ms, UCL=2524.6ms, relatively). The reverse was true of the colored treatments, where those that were grouped were detected faster (LSM = 1747.4ms, LCL=1564.9ms, UCL=1951.6ms vs. LSM=1843.7ms, LCL=1651.2ms, UCL=2059.2ms). Again, it could be theorized that color is effective in triggering bottom-up processing and the block of color in the grouped condition induces quick responses from participants.

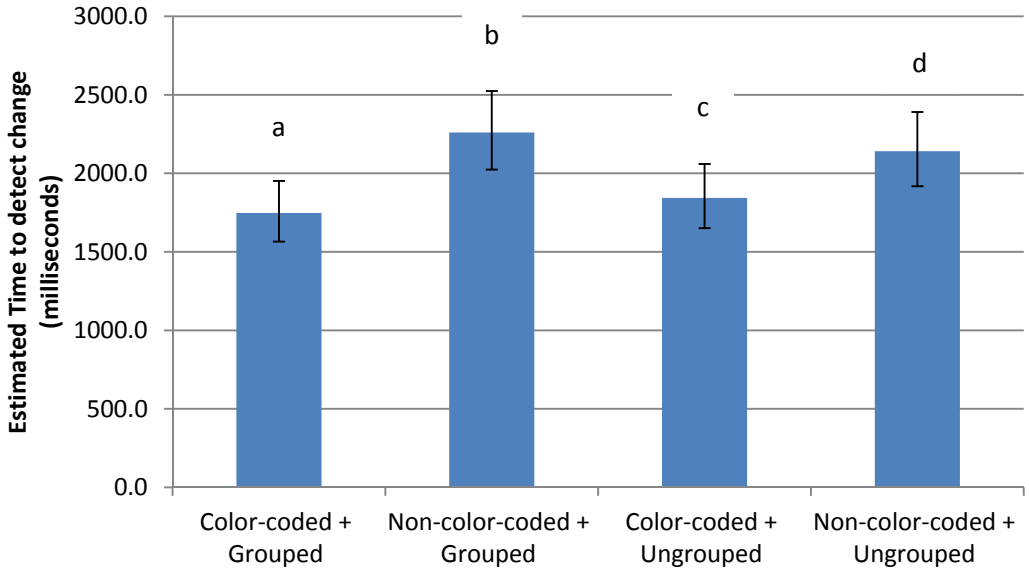


Figure 38. The effect of 'Color' and 'Grouping' and formats on Time to detect change: Estimated least square means (LSM) with estimated upper and lower limits. Differing letters indicate statistical significance at α=0.05.

4.3.3.2.3 Significant 2-way interaction terms: Grouping x Symbol

The time to detect changes also depended on both Grouping and Symbol. Within grouped conditions, symbol presence (LSM=1888.9ms, LCL=1691.2ms, UCL=2109.1ms) resulted in less time to detect changes than the symbol absent condition (p<0.0001: LSM=2091.7ms, LCL=1872.8ms, UCL=2336.1ms, Figure 38). However, there was no evidence of a significant difference in the time to detect change between grouped and ungrouped designs in the symbol presence format (p=0.1159). This was also true of the symbol absence format (p=0.1116, Figure 39).

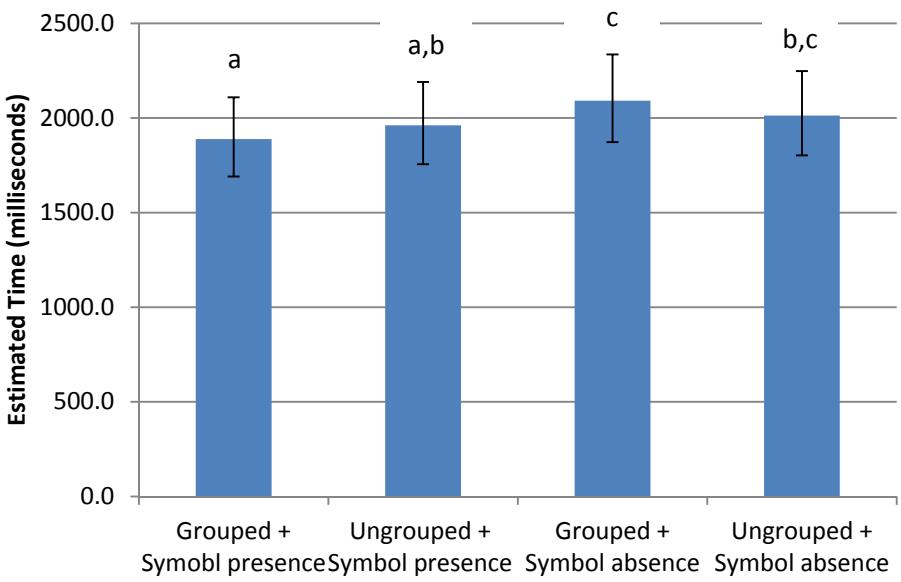


Figure 39. The effect of 'Grouping' and 'Symbol' formats on Time to detect change: Estimated least square means (LSM) with estimated upper and lower limits. Differing letters indicate statistical significance at α=0.05.

4.3.3.2.4 Significant 3-way interactions: Boxing x Symbol x Color

There was evidence of a significant interaction of Boxing x Symbol x Color on time to successful change detection (p=0.0323). As depicted in Figure 40, the design combinations of 'boxed/symbol present/color-coded' and 'boxed/symbol absent/color-coded' resulted in the fastest detection times (LSM = 1671.9ms, LCL=1489.7ms, UCL=1875.9ms vs. 1740.2ms LCL=1550.2ms, UCL=1953.0m, respectively). There was no evidence of a significant difference in the time to detect changes between these two designs above (p=0.2418).

Although 3-way interactions, this one included, are challenging to interpret, there are some interesting results provided that should be pointed out. The unboxed, non-colored, symbol absent treatment generated the largest response time (LSM=2669.9ms,

LCL=2378.5ms, UCL=2996.4ms), this was closely followed by treatments that were not boxed, with symbol and no color coding (LSM=2273.0ms, LCL=2025.8ms, UCL=2550.9ms). These represent the current approach to labeling, yet performed significantly worse than any other of the design combinations (α=0.05). Generally speaking, designs that had color-coding resulted in faster detection than those that did not. The combination of boxing with color coding (both symbols present & absent) generated the fastest responses.

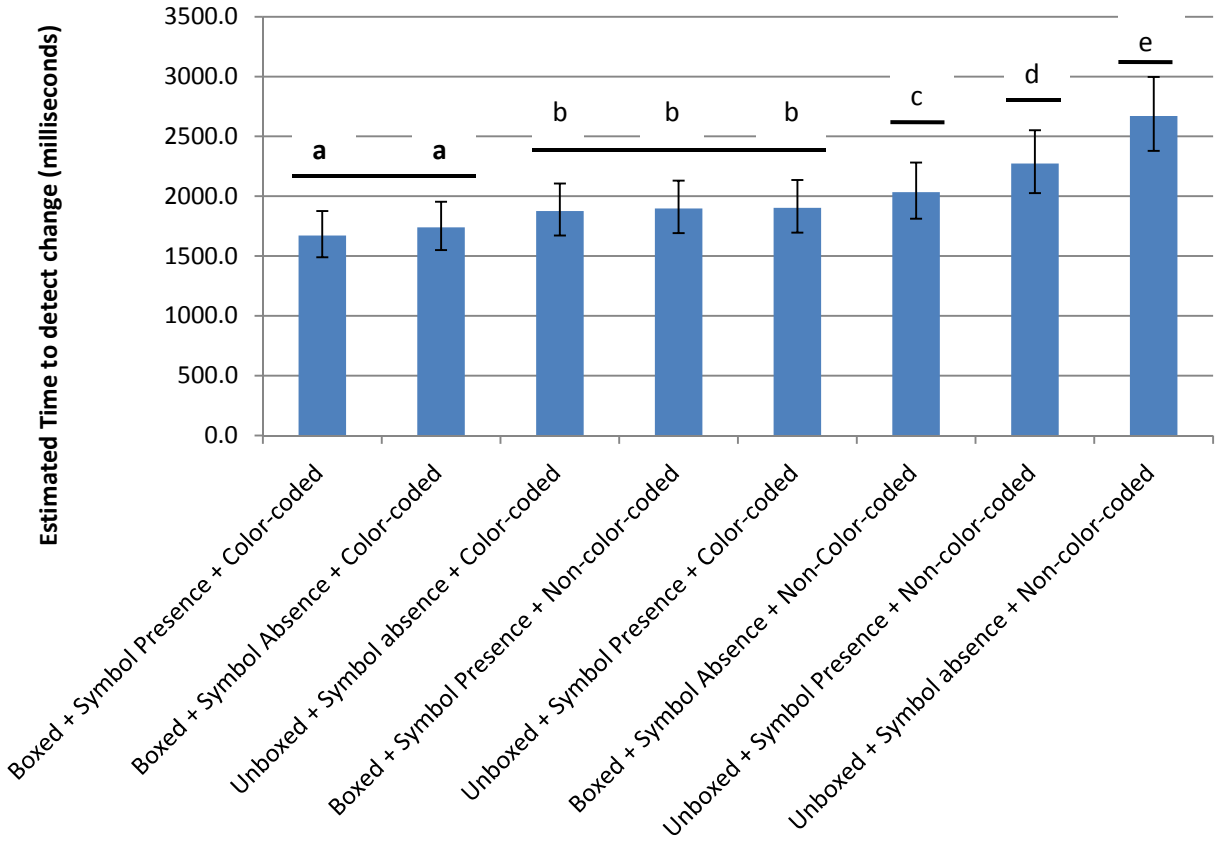


Figure 40. The effect of 'Boxing', 'Symbol' and 'Color' formats on Time to detect change: Estimated least square means (LSM) with estimated upper and lower limits. Differing letters indicate statistical significance at α=0.05.

4.3.4 Percentage statistics on symbol comprehension evaluation

Responses of participants on the meaning of medical device symbols were categorized according to the criteria described in the section of symbol evaluation methodology. The percentage data of all 5 response categories for 41 symbols is presented in Table 24.

Table 24. Percentage of each category response on medical device symbols						
Symbol No.	**Symbol Description**	**1 (correct)**	**2a (wrong)**	**2b (opposite meaning)**	**3 (Don't know)**	**4 (No response)**
1	Biological risks	75.5%	19.8%	0.0%	4.7%	0.0%
2	Do not re-use	45.4%	20.9%	1.2%	31.3%	1.2%
3	Consult instructions for use	71.0%	3.5%	0.0%	24.3%	1.2%
4	Caution, consult accompanying documents	76.7%	7.0%	0.0%	15.1%	1.2%
5	Fragile, handle with care	17.5%	50.0%	0.0%	26.7%	5.8%
6	Keep away from sunlight	32.5%	40.7%	2.3%	22.2%	2.3%
7	Protect from heat and radioactive sources	34.9%	29.1%	4.7%	27.8%	3.5%
8	Keep away from rain	37.3%	34.9%	15.1%	8.0%	4.7%
9	Lower limit of temperature	44.2%	23.3%	19.8%	11.5%	1.2%
10	Upper limit of temperature	47.7%	17.4%	16.3%	15.1%	3.5%
11	Temperature limitation	39.5%	26.7%	2.3%	28.0%	3.5%
12	Use by date	67.4%	17.4%	0.0%	15.2%	0.0%
13	Date of manufacture	38.4%	17.4%	0.0%	41.9%	2.3%
14	Batch code	95.3%	2.3%	0.0%	1.2%	1.2%
15	Catalog number	87.2%	3.5%	0.0%	8.1%	1.2%
16	Serial number	61.7%	7.0%	0.0%	29.0%	2.3%
17	Control	55.8%	12.8%	0.0%	22.1%	9.3%
18	Negative control	47.7%	10.5%	0.0%	32.5%	9.3%
19	Positive control	47.7%	9.3%	0.0%	33.7%	9.3%
20	Sterile	94.2%	0.0%	0.0%	2.3%	3.5%
21	Sterilized using ethylene oxide	71.0%	1.2%	0.0%	23.1%	4.7%
22	Sterilized using aseptic processing techniques	38.4%	2.3%	1.2%	48.8%	9.3%
23	Sterilized using irradiation	43.0%	5.8%	2.3%	40.8%	8.1%
24	Sterilized using steam or dry heat	72.1%	4.7%	0.0%	17.4%	5.8%
25	Do not resterilize	70.9%	23.3%	0.0%	5.8%	0.0%
26	Non-sterile	97.7%	0.0%	1.2%	1.1%	0.0%
27	Do not use if package is damaged	39.6%	27.9%	0.0%	27.8%	4.7%
28	In Vitro Diagnostic medical device	2.3%	27.9%	0.0%	61.7%	8.1%
29	Patient number	18.6%	32.6%	0.0%	43.0%	5.8%
30	Humidity limitation	14.0%	24.4%	0.0%	54.6%	7.0%
31	Atmosphere pressure limitation	2.4%	22.1%	0.0%	67.4%	8.1%
32	Sampling site	0.0%	50.0%	0.0%	43.0%	7.0%
33	Fluid path	0.0%	7.0%	0.0%	82.5%	10.5%
34	Non-pyrogenic	24.4%	15.1%	1.2%	51.2%	8.1%
35	Contains or presence of natural rubber latex	96.5%	1.2%	0.0%	1.1%	1.2%
36	Drops per milliliter	5.8%	68.6%	3.5%	18.6%	3.5%
37	Liquid filter with pore size	0.0%	29.1%	0.0%	60.4%	10.5%
38	One-way valve	0.0%	11.6%	0.0%	76.8%	11.6%
39	Latex-free	98.8%	1.2%	0.0%	0.0%	0.0%
40	Latex-free	100.0%	0.0%	0.0%	0.0%	0.%
41	Latex-free	98.8%	0.0%	0.0%	1.2%	0.0%

The percentage data of the correct responses (category 1) was analyzed statistically, using a “Proc Means” model of the statistical software SAS 9.3 (SAS Ins., Cary, NC). Through the “Proc Means” data analysis, means and Lower Confidence Limits (LCL) and Upper Confidence Limits (UCL) at the 95% confidence level were reported by percentage for the 41 symbols tested (Table 25). If the UCL of their percentage exceeds 85%, it was considered as passing comprehension testing, based on the ANSI 85% criterion (Table 25). The shaded rows in Table 26 depict “passing symbols”, based on this criterion.

Table 25. Percentage of correct response category on medical device symbols: Means and Upper & Lower Confidence Limits at 95% confidence level				
Symbol No.	**Symbol Description**	**Means**	**LCL**	**UCL**
1	**Caution, consult accompanying documents**	**76.7%**	**67.6%**	**85.9%**
2	**Batch code**	**95.3%**	**90.8%**	**99.9%**
3	**Catalog number**	**87.2%**	**80.0%**	**94.4%**
4	**Sterile**	**94.2%**	**89.1%**	**99.2%**
5	**Non-sterile**	**97.7%**	**94.4%**	**100.0%**
6	**Contains or presence of natural rubber latex**	**96.5%**	**92.6%,**	**100.0%**
7	**Latex-free***	**98.8%**	**96.5%**	**100.0%**
8	**Latex-free***	**100.0%**	**100.0%**	**100.0%**
9	**Latex-free***	**98.8%**	**96.5%**	**100.0%**
10	In Vitro Diagnostic medical device	2.3%	0.0%	5.6%
11	Atmosphere pressure limitation	2.4%	0.0%	5.6%
12	Sampling site	0.0%	0.0%	0.0%
13	Fluid path	0.0%	0.0%	0.0%
14	Liquid filter with pore size	0.0%	0.0%	0.0%
15	One-way valve	0.0%	0.0%	0.0%
16	Keep away from sunlight	32.5%	22.5%	42.7%
17	Protect from heat and radioactive sources	34.9%	24.6%	45.2%
18	Keep away from rain	37.3%	26.8%	47.6%
19	Lower limit of temperature	44.2%	33.5%	54.9%
20	Upper limit of temperature	47.7%	36.9%	58.4%
21	Temperature limitation	39.5%	29.0%	50.1%
22	Sterilized using radiation	43.0%	32.3%	53.7%
23	Drops per milliliter	5.8%	0.0%	10.9%
24	Biological risks	75.5%	66.3%	84.8%
25	Do not re-use	45.4%	34.6%	56.1%
26	Consult instructions for use	71.0%	61.1%	80.7%
27	Fragile, handle with care	17.5%	9.3%	25.6%
28	Use by date	67.4%	57.3%	77.5%
29	Date of manufacture	38.4%	27.9%	48.9%
30	Serial number	61.7%	51.1%	72.1%
31	Control	55.8%	45.1%	66.5%
32	Negative control	47.7%	36.9%	58.4%
33	Positive control	47.7%	36.9%	58.4%
34	Sterilized using ethylene oxide	71.0%	61.1%	80.7%
35	Sterilized using aseptic processing techniques	38.4%	27.9%	48.9%
36	Sterilized using steam or dry heat	72.1%	62.4%	81.8%
37	Do not resterilize	70.9%	61.1%	80.7%
38	Do not use if package is damaged	39.6%	29.0%	50.1%
39	Patient number	18.6%	10.2%	27.0%
40	Humidity limitation	14.0%	6.5%	21.4%
41	Non-pyrogenic	24.4%	15.2%	33.7%

*: non-standard symbols / shaded rows: passing symbols

Alarmingly, only 6 out of the 38 standard tested symbols passed the comprehension criterion specified by the ANSI standard at the 95% confidence level (see Table 26).

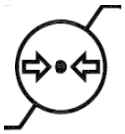
Table 26. Passing symbols in comprehension: Means and Upper & Lower Confidence Limits at 95% confidence level

Symbol	Correct meaning	Means	LCL	UCL
	Caution, consult accompanying documents	76.7%,	67.6%,	85.9%
	Batch code	95.3%	90.8%,	99.8%
	Catalog number	87.2%	80.0%	94.4%
	Sterile	94.2%	89.1%	99.2%
	Non-sterile	97.7%,	94.4%	100.0%
	Contains or presence of natural rubber latex	96.5%	92.6%,	100.0%

In addition, all of the three non-standard symbols identified in the benchmarking study passed the 85% criterion. One common factor that the passing symbols had was the incorporation of text within, except for one symbol of “Caution, consult accompanying documents”. This calls to question the efficacy of recognized symbols that do not utilize text, and is relevant given the current FDA proposal which would allow for incorporation of stand-alone symbols (if accompanied by a legend and recognized by an international standard).

The percentage data of the correct responses (category 1) was also analyzed

for low comprehension. The symbols which had an LCL at or below 10% in category 1 were “In-vitro diagnostic medical device”, “Atmosphere pressure limitation”, “Sampling site”, “Fluid path”, “Liquid filter with pore size”, “One-way valve”, “Drops per milliliter”, “Humidity limitation”, and “Fragile, handle with care” (see Table 27). Most of the symbols with poor comprehension levels were pictorial symbols which did not incorporate text in their symbol, except for “In-vitro diagnostic medical device”, “Liquid filter with pore size” and “Drops per milliliter”. The symbols which had 0% in comprehension were “Sampling site”, “Fluid path”, “Liquid filter with pore size”, and “One-way valve”. These symbols were newly added to the ANSI/AAMI/ISO 15223, in 2008, but are not included in ISO 15223.

Table 27. Symbols at less than 10% percentage in comprehension: Means and Upper & Lower Confidence Limits at 95% confidence level				
Symbol	**Correct meaning**	**Means**	**LCL**	**UCL**
	In-vitro diagnostic medical device	2.3%	0.0%	5.6%
	Atmosphere pressure limitation	2.4%	0.0%	5.6%
	Sampling site	0.0%	0.0%	0.0%
	Fluid path	0.0%	0.0%	0.0%
	Liquid filter with pore size	0.0%	0.0%	0.0%
	One-way valve	0.0%	0.0%	0.0%
	Drops per milliliter	5.8%	0.0%	10.9%
	Humidity limitation	14.0%	6.5%	21.4%
	Fragile, handle with care	17.5%	9.3%	25.6%

Wrong responses that were opposite to the intended meaning were coded as "2b". To be conservative, we only listed symbols as "Critically confusing symbols" when their Lower Confidence Limits exceed 5% in the 2b: the 5% cut off is defined by ANSI Z535.3.

The percentage data in the 2b category (wrong & opposite) for tested symbols

was analyzed statistically, using a “Proc Means” model of the statistical software SAS (Version 9.3, SAS Institute, Cary, NC). Through the “Proc Means” data analysis, Lower Confidence Limit (LCL) and Upper Confidence Limit (UCL) at the 95% confidence level are reported in Table 29. If the LCL of the 2b responses exceeded 5%, it was considered as a “critically confusing symbol” with regard to comprehension (Table 28).

Three symbols were found to fall into the category of “critically confusing symbols”. These symbols were: “Keep away from sunlight”, “Lower limit of temperature”, and “Upper limit of temperature”. See Table 28 for summation of failed symbols.

Table 28. “Critically confusing symbols”: Means and Upper & Lower Confidence Limits at 95% confidence level

Symbol	Correct meaning	Critically confused response (2b)	Means	LCL	UCL
	Keep away from rain	Waterproof, Impermeable, Impervious to rain, Water resistant, etc.	15.1%	7.3%	22.6%
	Lower limit of temperature	Keep cool, Keep at low temperature, Store below x temperature, Ok to store in cold places, etc.	19.8%	11.0%	28.0%
	Upper limit of temperature	Keep warm, Above boiling, Store above x temp, Ok to store in hot places	16.3%	8.2%	24.0%

4.4 Discussion

The sample population of this study was comprised of an experienced pool of healthcare providers (average experience years: 20, ranging from 1 to 51). Further, by sampling at conferences of a national, professional organization, it is not unreasonable

to assume that it included engaged providers from across the nation. That said, the providers we recruited were generalists. It is likely that specifically targeting specialists would yield different results.

The information focus groups in Cai's study identified as critical were also reported as critical in the survey results reported herein (see Table 21). In addition, the recommendations for improvement to labeling design were also very similar to what Cai suggested (see Table 23)

4.4.1 Change Detection

In order to evaluate the effect of four design factors (Grouping, Boxing, Symbol and Color) on the three pieces of critical information as identified by Cai's study (2012) in early stages of information processing (i.e. attention), we employed a change detection method. In doing so, we enumerated the effect of the varied designs on attention.

The probability of successful change detection within the 60 second window was found to be extremely high across all the four design factors. Even though there was evidence of a main effect of two design factors (Grouping and Color), the difference in successful detection was less than 1%. This finding suggests that participants had enough time to detect changes for all the treatments of evaluated labeling designs, that is, participants were at ceiling.

We also employed time to successful change detection as a response variable. Analysis revealed that multiple 2-way and one 3-way interactions were evident.

Participants responded more quickly to changes in the three pieces of critical information when the format was boxed than when unboxed, in the grouped design.

(p=0.0086). This was also true in the ungrouped design (p<0.0001, Figure 37). However, when boxed and ungrouped, rates of detection were significantly faster than those boxed and grouped. The opposite was true in the unboxed condition. That is, when information was grouped, respondents found changes faster than when ungrouped, which took the longest time overall. However, the opposite effect of grouping was indicated for non-colored designs, whereby those that were grouped took significantly more time to successful detection (LSM=2260.5ms, LCL=2024.0ms, UCL=2524.6ms) than those that not (LSM=2140.9ms, LCL=1917.3ms, UCL=2391.1ms). And, there was no evidence of a significant effect of grouping to the time to detect changes in the symbol present condition (p=0.1159). This result was also true in the symbol absent condition (p=0.1116).

This unexpected finding regarding effect of grouping might result from an experimental design context of our change detection. In bottom-up processing, incoming data is a critical piece influencing attention and perception (Goldstein, 2007). In our change detection experiment, the incoming data which participants needed to detect involved a piece of flickering critical information in the varied designs. In the boxed, grouped design, only one out of three pieces of critical information in a large rectangular box that encompassed all three pieces of information flickered; in the boxed, ungrouped condition, the box surrounded nothing but the flickering information. If the box is the salient feature of the scene, it could explain the result found herein. That is, responses to the grouped, boxed condition took significantly longer than the ungrouped, boxed condition (where the salient item was close by the flickering information).

Colored designs catalyzed significantly faster change detection in the grouped

treatment than non-colored designs ($p<0.0001$). This was also true in the ungrouped treatment ($p<0.0001$). This result reflects findings of previous research on a significant effect of color presence: color-coded nutrition information on a cereal Front-Of-Panel (Sundar, 2013).

Three design factors (Boxing, Symbol and Color) significantly interacted when the dependent variable was time to detect changes ($p<0.0323$). The designs of 'boxed/symbol present/color-coded' and 'boxed/symbol absent/color-coded' enabled participants to detect changes significantly faster than other mixed designs. This reflects that box and color were the important salient features, resulting in faster detection times.

4.4.2 Symbol Comprehension

It is likely that many manufacturers will take advantage of the opportunity to gain label space by utilizing symbols from recognized standards if the proposed rule is enacted by the US FDA.

Our work supports the work of others (Liu et al., 2004 and Hermans et al., 2011) that suggests that the comprehension level for internationally published symbols for medical device packaging is quite poor. This was despite the fact that we recruited from an experienced pool of healthcare providers from throughout the nation (see Figure 32). Only 6 out of 38 standard symbols passed the 85% criterion (see Table 25). This poor comprehension result echos those reported by Liu et al. (2004) and Hermans et al. (2011), who tested comprehension levels of medical device symbols with populations outside of the US.

A common characteristic of successful symbols was the inclusion of supplementary text within the symbol (see Table 26). Most of the symbols that were correctly defined by less than 10% of respondents did not incorporate text within the symbols (see Table 27). Perhaps most concerning is the fact that 3 of the symbols that we tested were categorized as “critically confusing” according to the ANSI Z535.3 criteria. In other words, at least 5% of respondents (as defined with an LCL of more than 5%) indicated a meaning opposite to the defined, intended meaning of the symbol (see Table 28).

In light of a very limited body of work (Liu et al., 2004 and Hermans et al., 2011), all of which suggests poor comprehension rates for standard symbols, policy changes should be carefully considered.

CHAPTER 5

DESIGN FEATURES (BOXING, GROUPING, SYMBOL AND COLOR CODING) INFLUENCE ON INFORMATION PROCESSING DURING A FORCED CHOICE TASK

5.1 Objective & Hypothesis

- **Objective** – Investigate the efficacy of *Boxing, Grouping, Symbol presence and Color-coding to critical information, during most stages of information processing*
- **Hypothesis** - It is hypothesized that a standard location and format of information deemed to critical to care will have a higher rate of correct response and shorter time to correct response during most stages of information processing.

5.2 Methodology

5.2.1 Subjects

Healthcare professionals were recruited at the Association of Surgical Technologists (AST) conferences in Savannah, GA and Denver, CO, and using a targeted e-mail (see Appendix 13) of AST members within a 30 mile radius of Lansing, MI. The screening criteria in recruitment were:

- Be over 18 years of age
- Not be legally blind
- Be a healthcare professional, or a student in a healthcare field.

Eighty-nine perioperative personnel (primarily surgical technologists and nurses) participated to evaluate the efficacy of varied designs for critical information common to

medical device packages. This study was conducted using procedures approved under IRB # 13-698. A research consent form was provided to subjects to acquire their informed consent (see Appendix 10). Prior to the forced choice task, participants were characterized in numerous ways, including: visual acuity, color blindness, health literacy and demographics. A questionnaire was given to subjects to collect subject demographic and job-related information (see Appendix 7).

5.2.2 Materials and methods

Labels were developed using Adobe Illustrator CS 3.0. Their size was 1280 pixels wide by 768 pixels tall. Each label was divided into 4 sectors for randomization as explained in the methodology section of the change detection experiment. A size of one sector image in a label was 256 pixels wide by 192 pixels tall.

Test labels were created in combinations of boxing, grouping, symbols (absence and presence) and color. Two color coding treatments (color-coded vs. non-color-coded) were developed using green/white, red/white and black/white colors as presented in Table 29.

Table 29. Color coding formats: Forced Choice Task		
Critical information	**Color-coded**	**Non-color-coded**
Latex	 Caution: This product Contains Natural Rubber Latex Which May Cause Allergic Reactions.	 Caution: This product Contains Natural Rubber Latex Which May Cause Allergic Reactions.
Latex-free	 This product is not made with Natural Rubber Latex.	 This product is not made with Natural Rubber Latex.
Sterile	 Sterile: Unless package is opened or damaged.	 Sterile: Unless package is opened or damaged.
Non-sterile	 Non-sterile: Device inside package is not sterilized.	 Non-sterile: Device inside package is not sterilized.
Expired	 USE BY 2010-07*	 USE BY 2010-07
Unexpired	 USE BY 2015-08*	 USE BY 2015-08

*In color coded trials of expiration date, the latex and sterility status appeared as color-coded information; expiration date appeared in black and white.

For the sake of comparison, two commercial labels were broken into 4 sectors (see Figures 43 and 44). They comprised six forced choice trials (2 brands x 3 pieces of critical information, see Table 31).

Labels that we designed were also created. For these labels, we evaluated four design factors, each at two levels: Boxing (boxed and unboxed), Grouping (grouped and

ungrouped), Symbol (absent or present) and Color coding (absent or present). Conditions were crossed for a total of sixteen treatments of interest (2 x 2 x 2 x 2).

During each forced choice task, two labels appeared on the screen (Figure 41 and 42). These labels only differed in one aspect, a single piece of critical information was changed (e.g. one was sterile, the other not). Trials were conducted with mock brands (16 treatments x 3 pieces of information) (Table 30) and six trials with two labels which emulated commercial labels (Figures 43 and 44) based on our benchmarking results. As such, there were 54 trials in total (48 trials for newly developed labels + 6 commercial trials (2 brands x 3 critical information) for this forced choice task (Table 30 and 31).

Testing was conducted using E-Prime 2.0 (Psychology Software Tools, Inc.), and trial order was randomized to mitigate any run order effects. As with the change detection trials, images were divided into 4 sections, with individual sections randomized to mitigate any location effects (Figure 41 and 42). However, these randomizations were “yoked” such that the sections, and therefore the two comparative labels were the same in all aspects other than the difference involving the selection question for each pair in the choice.

Table 30. Matrix chart of Forced Choice Tasks: Newly developed labels						
Critical information	**Grouping**	**Color coding**	**Symbol with text**		**Text only without symbol**	
			Boxed	**Unboxed**	**Boxed**	**Unboxed**
Sterile vs. Non-sterile	Ungrouped	Color-coded	1	2	3	4
		Non color-coded	5	6	7	8
	Grouped	Color-coded	9	10	11	12
		Non-color coded	13	14	15	16
Latex vs. Latex-free	Ungrouped	Color-coded	17	18	19	20
		Non color-coded	21	22	23	24
	Grouped	Color-coded	25	26	27	28
		Non color-coded	29	30	31	32
Expired vs. Unexpired	Ungrouped	Color-coded	33	34	35	36
		Non color-coded	37	38	39	40
	Grouped	Color-coded	41	42	43	44
		Non color-coded	45	46	47	48

Table 31. Matrix chart of Forced Choice Tasks: Commercial labels		
Image Type	**Critical Information**	**Cell #**
Commercial label A	‘Sterile’ vs. ‘Non-sterile’ label	1
	‘Latex’ vs. ‘Latex-free’ label	2
	‘Expired’ vs. ‘Unexpired’ label	3
Commercial label B	‘Sterile’ vs. ‘Non-sterile’ label	4
	‘Latex’ vs. ‘Latex-free’ label	5
	‘Expired’ vs. ‘Unexpired’ label	6

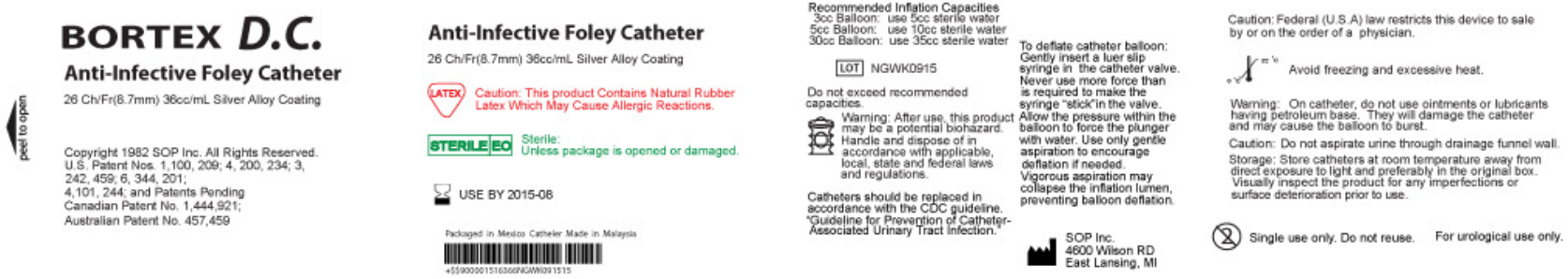
Just prior to each trial, participants were provided with instructions to select a specific product (e.g. select the sterile device; select the latex containing device; select the expired device) as quickly as possible (see Table 32 and Figure 41 & 42). Selection was made by depressing either “ ↑ ” (UP ARROW) or “ ↓ ” (DOWN

ARROW) on a keyboard entry system (corresponding with the label in the upper or lower position, respectively) within 1 minute.

Table 32. Questions of Forced Choice Tasks	
'Sterile' vs. 'Non-sterile' label	**For the next pair, please select the device that IS STERILE.** **Press " ↑ " (UP ARROW) for the top device or** **Press " ↓ " (DOWN ARROW) for the bottom device.**
'Latex' vs. 'Latex-free' label	**For the next pair, please select the device that HAS LATEX.** **Press " ↑ " (UP ARROW) for the top device or** **Press " ↓ " (DOWN ARROW) for the bottom device.**
'Expired' vs. 'Unexpired' label	**For the next pair, please select the device that IS EXPIRED.** **Press " ↑ " (UP ARROW) for the top device or** **Press " ↓ " (DOWN ARROW) for the bottom device.**

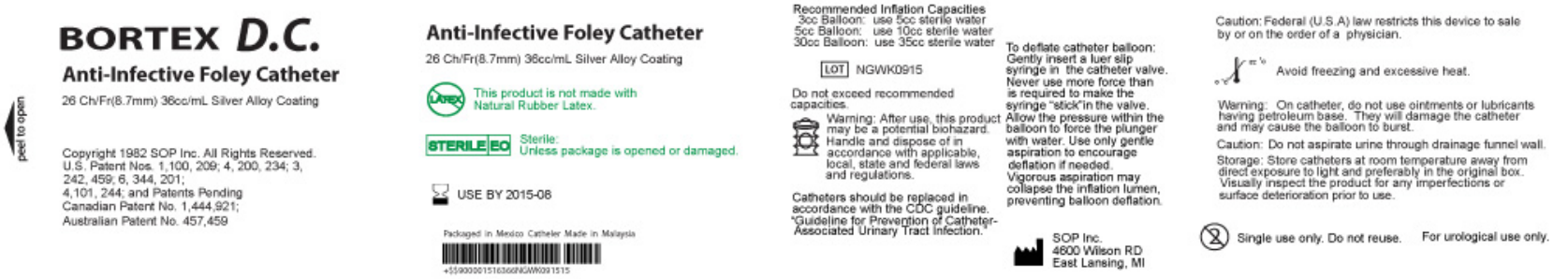
The position of the correct choice was counter-balanced between subjects for each combination of treatments. For instance, if the latex containing product for a label that had color, grouping, symbol and boxed information appeared on top for subject one, it would appear on the bottom for subject two. For each subject, a correct choice for 27 trials took place at the top location and the remaining trials took place at the bottom location. This was accomplished with a set of stimulus and A & B sets, which were rotated between subjects. In this experiment, 44 subjects participated in the type-A forced choice task; 45 subjects, in the type-B forced choice task. Order of presentation of the complete set of 54 choices and the position of the section containing the information critical to the choice, was randomized.

Top image.



Section 1 *Section 2* *Section 3* *Section 4*

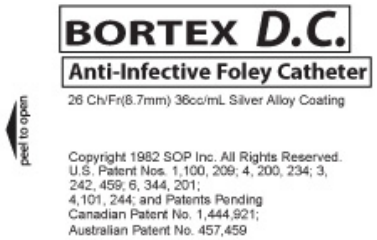
Bottom image



Section 1 *Section 2* *Section 3* *Section 4*

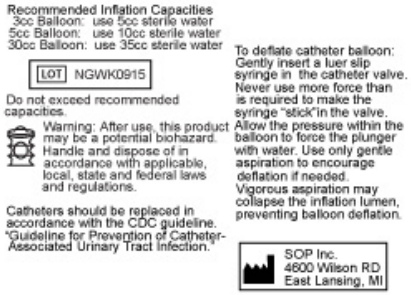
Figure 41. Test cell # 26 from Table 30 (Latex vs. Latex free information)

Top image.

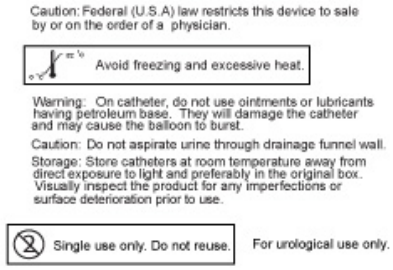


Section 1

Section 2

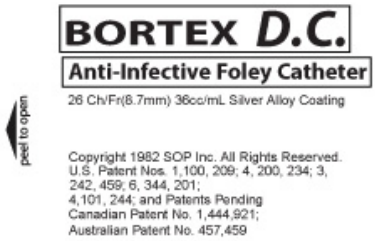


Section 3



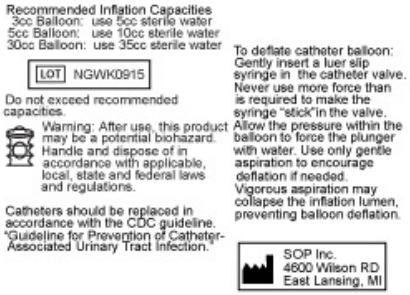
Section 4

Bottom image

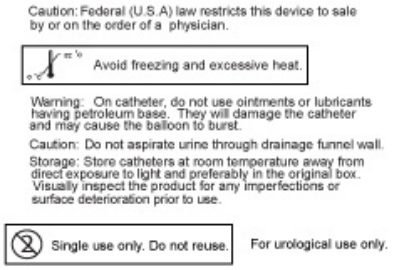


Section 1

Section 2



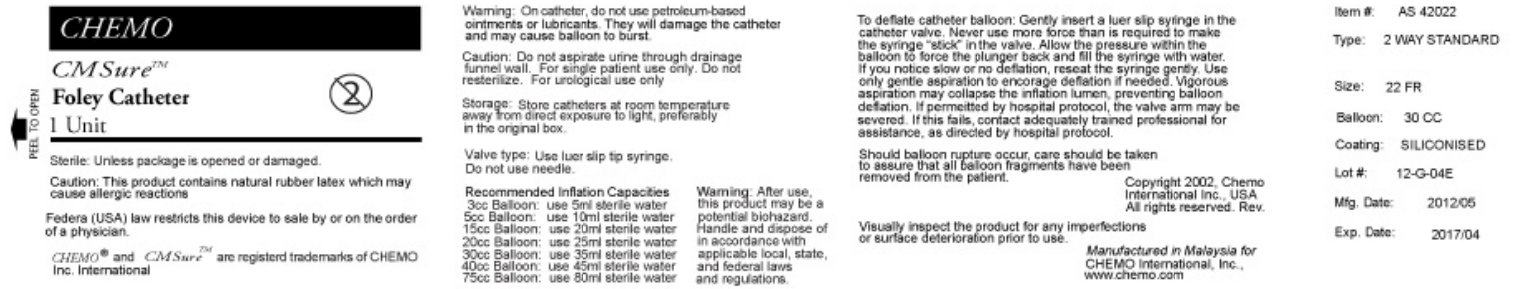
Section 3



Section 4

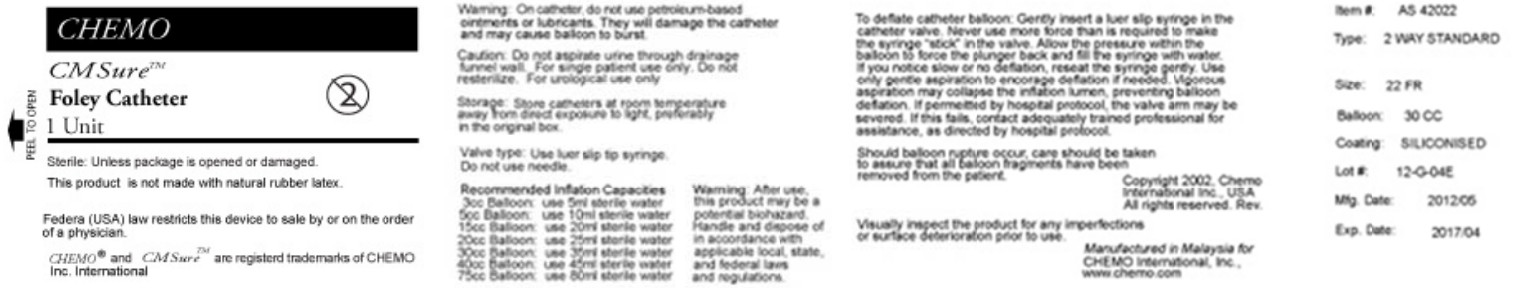
Figure 42. Test cell # 25 from Table 30 (Latex vs. Latex free information)

Top image.



Section 1 *Section 2* *Section 3* *Section 4*

Bottom image



Section 1 *Section 2* *Section 3* *Section 4*

Figure 43. Commercial label A (Latex vs. Latex free)

Top image.

Section 1 *Section 2* *Section 3* *Section 4*

Bottom image

Section 1 *Section 2* *Section 3* *Section 4*

Figure 44. Commercial label B (Latex vs. Latex free)

5.3 Results

5.3.1 Subject demographics

Eighty-nine healthcare professional were recruited at the Association of Surgical Technologists (AST) conferences in Savannah, GA and Denver, CO, and using a targeted e-mail (see Appendix 12) of AST members within a 30 mile radius of Lansing, MI. The average age of participants was 45 years old (ranging from 18 to 66, median: 47). Figure 45 provides information regarding the age of the test population.

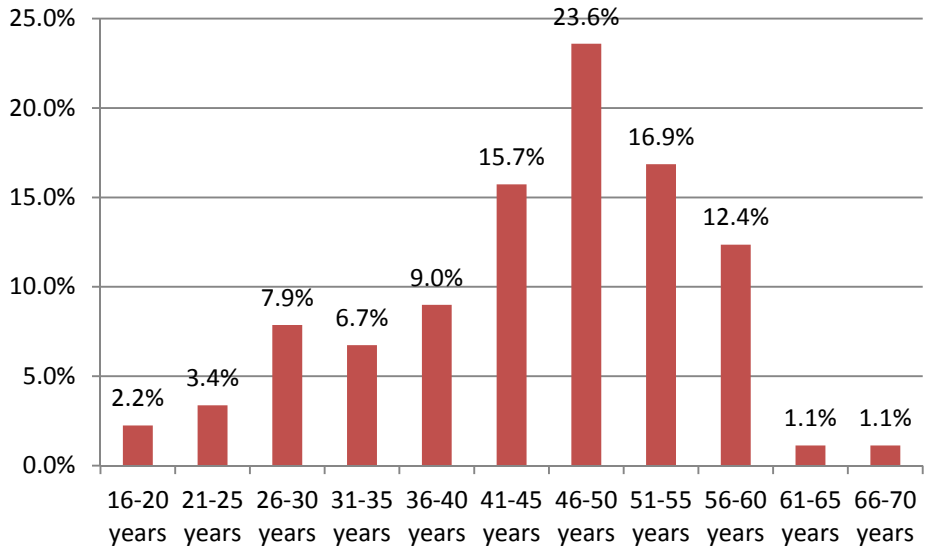


Figure 45. Age of participants

Of the 89 participants, 16 were male; 73, female. Eighty-seven participants used English as a native language; two subjects reported English as a secondary language. More details on the demographics information are presented in Figure 46.

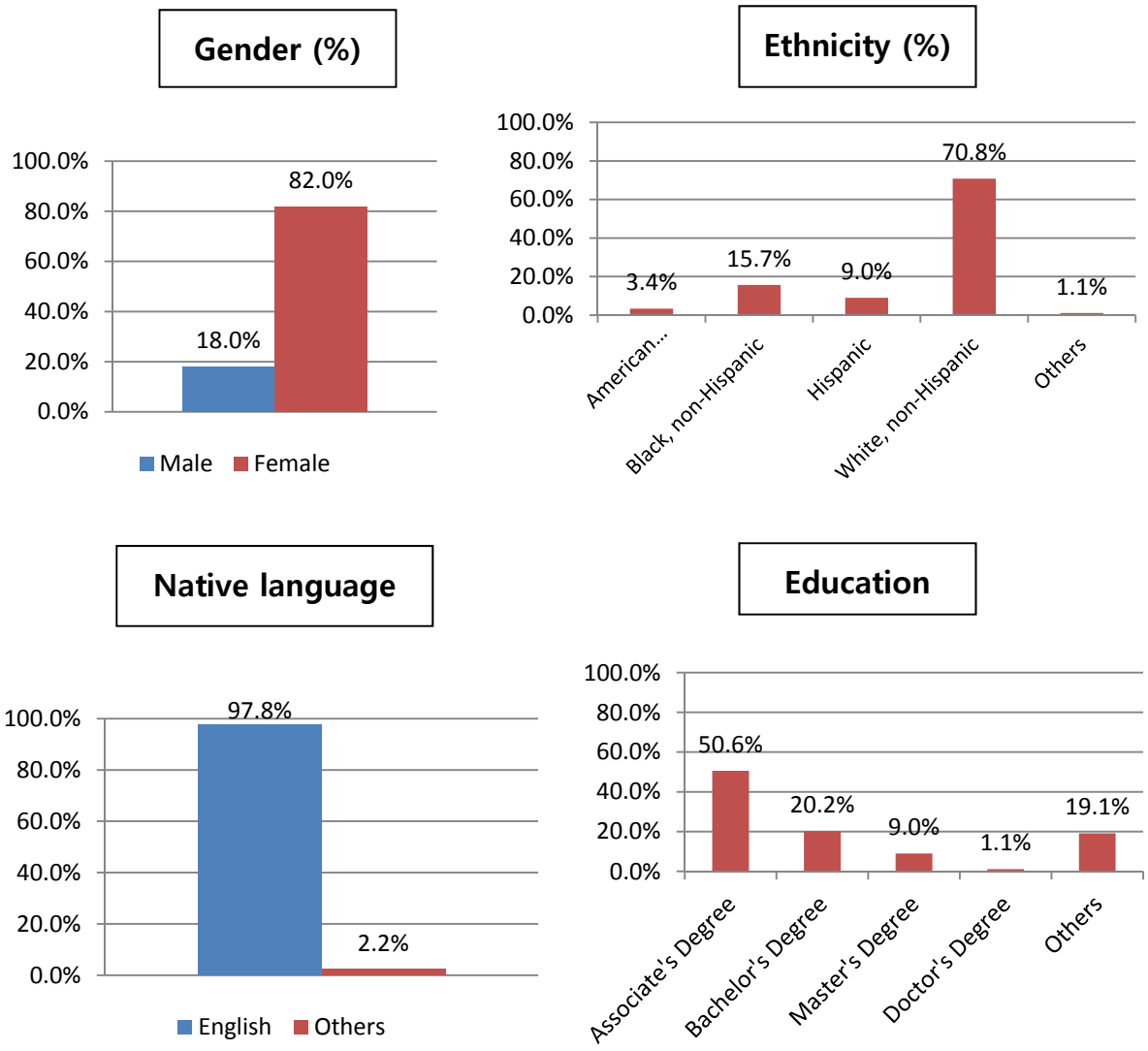


Figure 46. Demographics information (%) of participants on gender, ethnicity, native language and education (highest level achieved)

Three pre-tests regarding visual acuity, color blindness and health literacy were conducted prior to the forced choice task. The details of the pre-test results are presented in Figure 47.

Figure 47. Subject characteristics (%) on visual acuity, color blindness and health literacy

5.3.2 Descriptive statistics on questionnaire evaluation

5.3.2.1 Years of experience

On average, the subject population had 21 years of experience (ranging from 0 to 51, median: 22). Figure 48 characterizes the subject population with regard to years of experience.

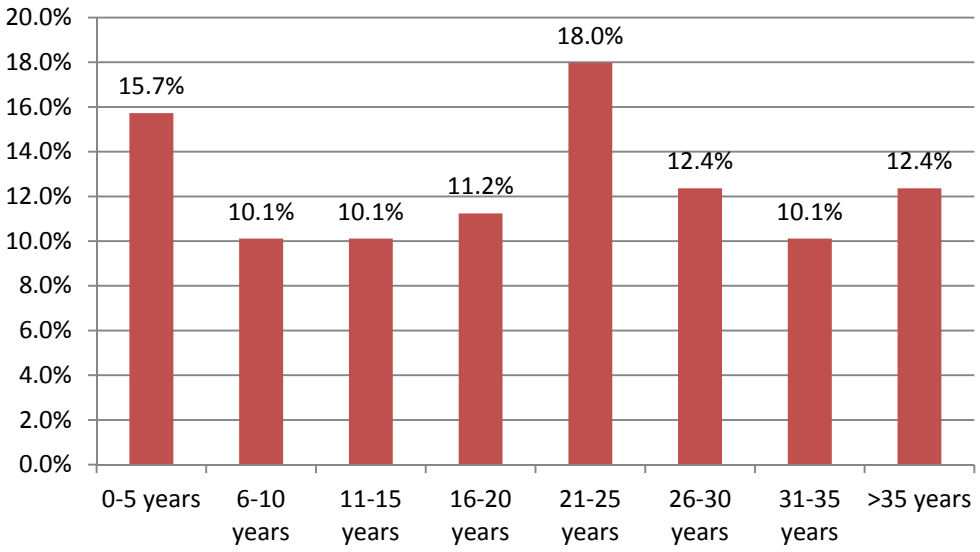


Figure 48. Experience in years

5.3.2.2 Employment settings

Healthcare providers work in diverse care settings. Figure 49 provides an indication of the frequency of employment setting as self-reported by participants.

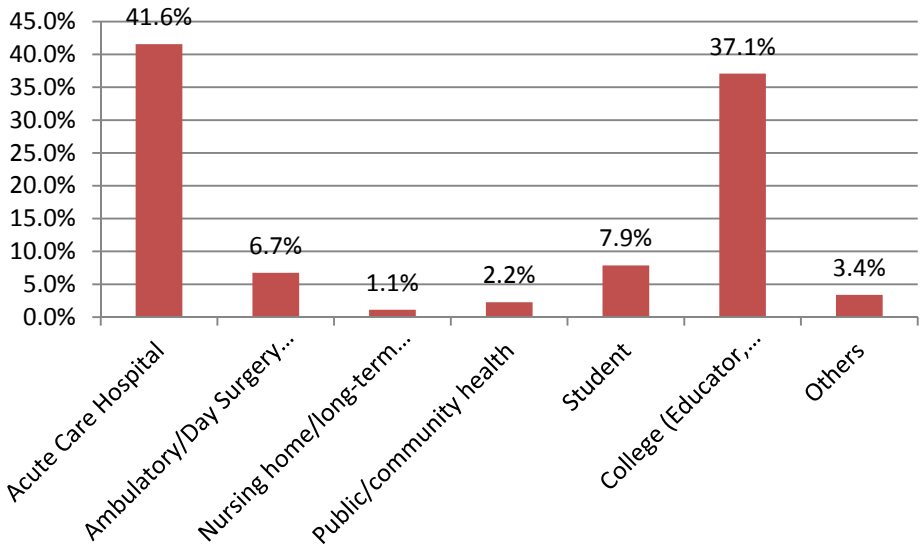


Figure 49. Employment settings of participants (%)

5.3.2.3 Position & role

Figure 50 depicts the roles of participants in healthcare.

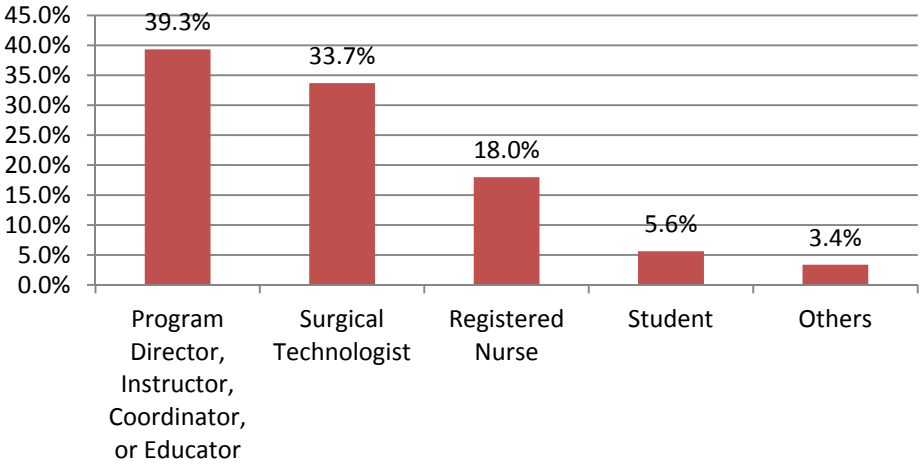


Figure 50. Position & role of participants (%)

5.3.2.4 Critical pieces of labeling information

Participants were asked to record the information from medical device labeling from most important (1) to least important (4) (see Survey - Appendix 7). Researchers categorized participant responses (post-hoc) into 15 response groups (see Appendix 16). The total frequencies of the top five responses, and their median and mode are presented in Table 33.

Table 33. Critical pieces of labeling information with top 5 out of 15 response groups

	Expiration dating	Sterility status	Latex status	Product Name	Use Instructions
1 (Most important)	22	20	10	18	4
2	25	20	17	9	7
3	20	15	15	10	7
4 (Least important)	11	4	17	5	8
Total Frequency of Participant Responses	78	59	59	42	26
Median Ranking	2	2	3	2	3
Mode Ranking	2	1,2	2,4	1	4

This result closely parallels results collected from participants of the change detection experiment (see Table 20).

5.3.2.5 Critical labeling problems

Participants were asked to record problems that resulted from labeling on a response sheet (see Survey - Appendix 7). Responses were ranked from 1st (most problematic) to 4th (least problematic) items in this category, and grouped into 10

responses (see Appendix 17). The total frequencies of the top five response groups, and their median and mode are presented in Table 34.

Table 34. Critical labeling problems with top 5 out of 10 response groups

Ranking	Small font size	No standard location for critical information	No color contrast	No color coding	Labeling designs not standardized
1 (Most problematic)	47	16	9	5	1
2	20	14	17	15	6
3	10	19	12	9	6
4 (Least problematic)	3	5	3	4	5
Total Frequency of Participant Responses	80	54	41	33	18
Median Ranking	1	2	2	2	3
Mode Ranking	1	3	2	2	2,3

These top 5 response groups were also reported in the change detection experiment survey. But, the ranking of frequencies of 'no color contrast', 'no color coding' and 'labeling designs not standardized' was identical each other between the surveys (see Tables 21and 34).

5.3.2.6 Medical errors due to labeling issues

Participants were asked to record medical errors involving labeling that they had been involved with (see Survey - Appendix 7). Participants' responses were categorized into 6 groups. Their total frequencies are presented in Table 35.

Table 35. Medical errors participants experienced due to labeling issues	
Response groups	**Total frequencies**
Wrong product/size opening or use	31
Expired product opening or use	27
Unsterile product opening or use	17
Incorrect dosage	15
Latex-containing product opening or use to latex-allergy patients	13
Other medical errors	20

The five shaded responses on medical errors were those that were reported in the change detection experiment survey. The ranking of frequencies of 'unsterile product opening or use', 'incorrect dosage' and 'latex-containing product opening or use to latex-allergy patients' was not identical each other between the surveys (see Tables 22 and 35).

5.3.2.7 Recommendations on labeling designs

Suggestions regarding the resolution of labeling problems were also collected from research participants. Suggestions were then categorized into 8 response groups. Response frequencies are summed in Table 36

Table 36. Suggested recommendations to resolve labeling problems	
Response groups	**Total frequencies**
Bigger or bolder font size	60
Color coding	46
Standard location for labeling information	40
Clear color contrast	23
Standardization for labeling designs	14
Highlighted critical information	11
Standardized symbols	3
Others	16

The seven shaded recommendations to improve labeling related problems were the same as those that were reported in the change detection experiment survey. The

ranking of frequencies of ‘clear color contrast’, ‘standardization for labeling designs’ and ‘highlighted critical information’ was identical each other between the surveys (see Tables 23 and 36).

5.3.3 Statistical analysis on Forced Choice Tasks

Two response variables were collected for analysis from E Prime® software for each forced choice task trial:

- A binary variable: Correct choice (Yes/No) prior to timing out at 60 seconds
- A continuous variable: Time taken to make a correct choice (milliseconds) prior to timing out at 60 seconds.

5.3.3.1 Binary Variable – correct choice (Yes/No)

A generalized linear mixed model was fitted to this binary variable – correct choice (yes/no or timeout at 60 seconds) using a logit-link function to model the probability of correct choice (in %). Commercial label trials were not included in this data analysis. Linear predictors in this model were four design factors (grouped vs. ungrouped + boxed vs. unboxed + symbol presence vs. symbol absence + color-coded vs. non-color-coded), and all possible 2-way, 3-way and 4-way interactions were analyzed.

From the demographic information collected, ethnicity ($p=0.0230$) was retained in the final model, based on their Type III p values ($\alpha=0.05$).

The model was fitted using the GLIMMIX procedure of SAS 9.3 (SAS Ins., Cary, NC). Estimated least square means (LSM) and corresponding 95% confidence

intervals (LCL=Lower Confidence Limit and UCL=Upper Confidence Limit) were reported in the percentage of probability of correct choices.

4,053 (94.9%) out of the 4,272 trials (48 trials x 89 subjects) resulted in correct choices; 219 trials (5.1%) had the incorrect product chosen.

There was evidence of a main effect of two factors on the probability of correct choice: Boxing ($p=0.0101$) and Symbol ($p<0.0001$). The LSM difference between the boxed and unboxed treatments was 1.4%. The unboxed treatment resulted in a higher rate of correct choices that the boxed treatment (Figure 51). The LSM difference between the symbol presence and symbol absence treatments was 3.3%. The symbol presence treatment resulted in a higher rate of correct choices than the symbol absence treatment (Figure 52).

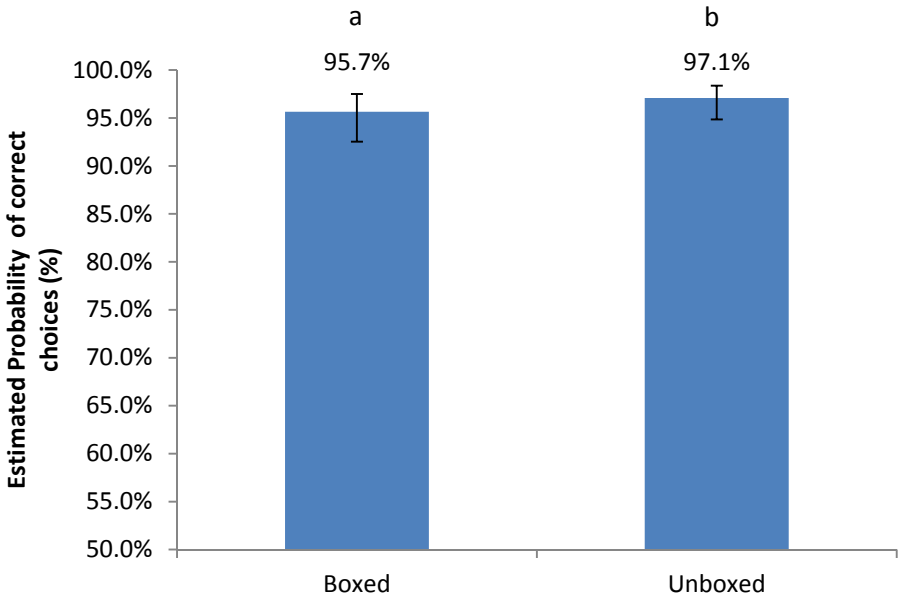


Figure 51. The effect of 'Boxing' on Probability of correct choice: Estimated least square means (LSM) with estimated upper and lower limits. Differing letters indicate statistical significance at $\alpha=0.05$.

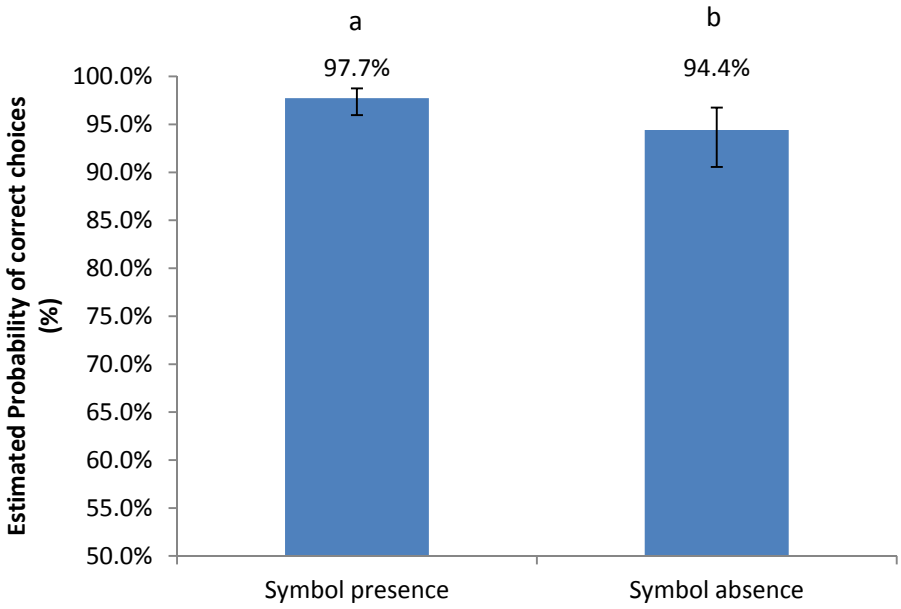


Figure 52. The effect of 'Symbol' on Probability of correct choice: Estimated least square means (LSM) with estimated upper and lower limits. Differing letters indicate statistical significance at α=0.05.

5.3.3.2 Continuous Variable: Time taken to make a correct choice (milliseconds)

For critical trials that were correctly chosen prior to timing out at 60 seconds, a second variable, "time to make a correct choice," was recorded in milliseconds. Commercial label trials were not included in this data analysis. Gender, age, ethnicity, education level, visual acuity, health literacy, color blindness, ethnicity, native languages, and choice location were included in the model as explanatory covariates. The data was log-transformed to meet normality assumptions. Similar to the analysis for the previous variable, linear predictors in this model were the four design factors (grouped vs. ungrouped + boxed vs. unboxed + symbol presence vs. symbol absence + color-coded vs. non-color-coded, and all possible 2-way, 3-way and 4-way interactions were analyzed.

Age ($p<0.0001$) and ethnicity ($p=0.0084$) were retained in the final model, based on their Type III p values ($\alpha=0.05$). Correct choice location, which was randomized in each trial by EPrime® software, had a significant effect ($p=0.0005$) on the dependent variable (time to make a correct choice), and, as such, was included as a random variable in the final model, based on its Type III p values ($\alpha=0.05$).

The model was fitted using the Mixed procedure of SAS (Version 9.3, SAS Institute, Cary, NC). Estimated least square means (LSM) and corresponding 95% confidence intervals (LCL=Lower Confidence Limit and UCL=Upper Confidence Limit) were reported in the original millisecond scale. Relevant pairwise comparisons were conducted, using Fisher's LSD.

There was significant evidence for a main effect of three design factors: Grouping ($p=0.0104$), Symbol ($p<0.0001$) and Color ($p<0.0001$). No interaction terms yielded evidence of significant differences.

5.3.3.2.1 Significant main terms: Grouping, Symbol and Color

Participants took significantly less time to make a correct choice when the pieces of critical information were grouped (LSM=4202.4ms, LCL=3637.5ms, UCL=4856.2ms, when compared with those that were ungrouped (LSM=4407.6ms, LCL=3814.2, UCL=5093.3; $p<0.0104$, see Figure 53).

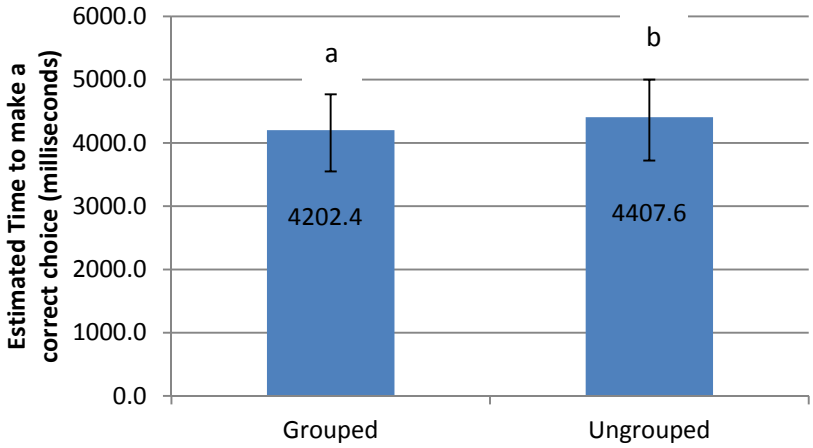


Figure 53. The effect of 'Grouping' on Time to make a correct choice: Estimated least square means (LSM) with estimated upper and lower limits. Differing letters indicate statistical significance at α=0.05.

Symbol use also positively impacted the time to correctly select a product (LSM=3820.3, LCL=3306.7, UCL=4413.7; p<0.0001, see Figure 54).

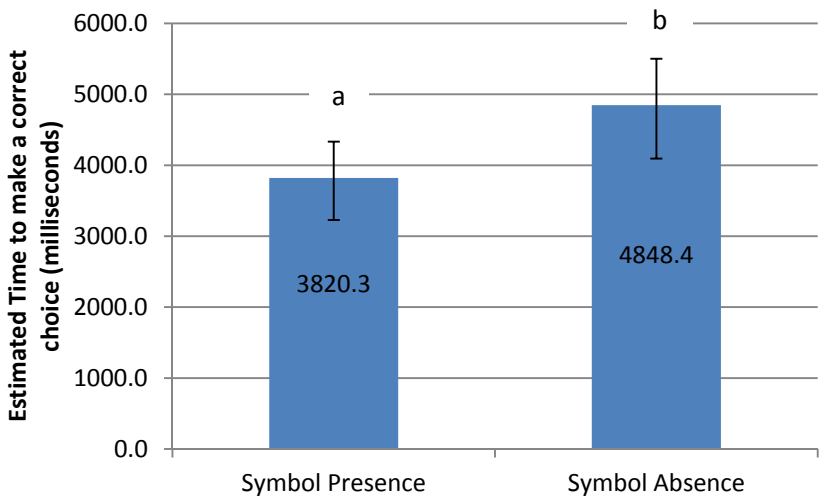


Figure 54. The effect of 'Symbol' on Time to make a correct choice: Estimated least square means (LSM) with estimated upper and lower limits. Differing letters indicate statistical significance at α=0.05.

Color also decreased time to correct selection of products (LSM=3922.8, LCL=3394.7, UCL=4532.1; p<0.0001, see Figure 55).

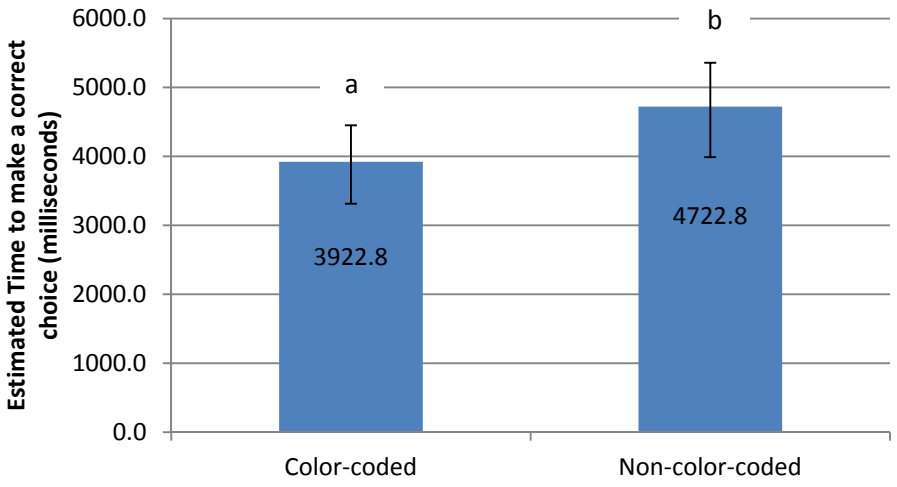


Figure 55. The effect of 'Color' on Time to make a correct choice: Estimated least square means (LSM) with estimated upper and lower limits. Differing letters indicate statistical significance at α=0.05.

5.3.3.3 Pairwise comparisons between optimal (grouped + symbol present + color-coded) label and commercial labels

Since grouping, symbol presence and color-coding design indicated evidence of a significant benefit on the time to make a correct choice, the combined design label of these three factors (referred to as “optimal label”, see Figures 56 and 57) on the probability of making a correct choice and the time to make a correct choice was compared with two commercial labels (see Figures 43 and 44).

5.3.3.3.1 Binary Variable: Probability of correct choice (Yes/No)

The optimal label (LSM=97.3%, LCL=95.5%, UCL=98.4%) resulted in a significant positive benefit regarding the probability of correct choice during the forced choice task, as compared to the two commercial labels we tested (LSM=92.0%, LCL=87.9%, UCL=94.7%, and LSM=89.8%, LCL=85.3%, UCL=93.0%; p’s<0.0001, see Figure 56).

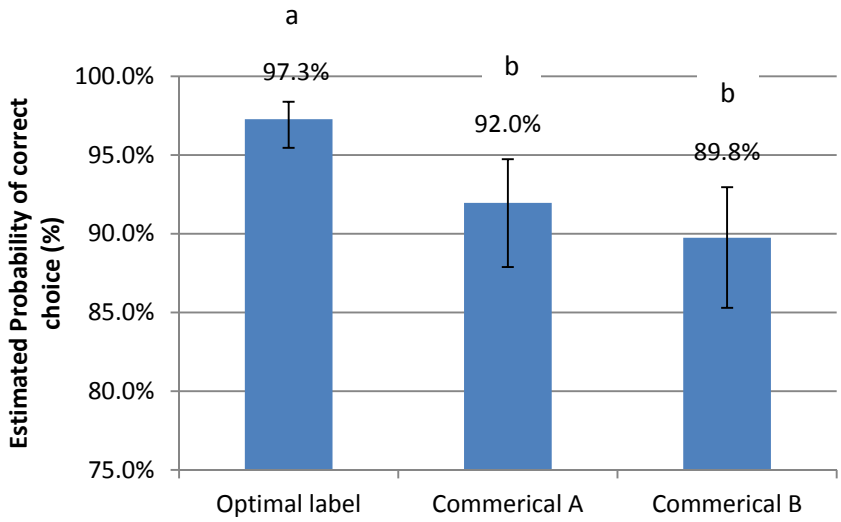


Figure 56. The effect of ‘Grouped + Symbol presence + Color-coded’ design on Probability of correct choice, compared to commercial label designs: Estimated least square means (LSM) with estimated upper and lower limits. Differing letters indicate statistical significance at α=0.05.

5.3.3.3.2 Continuous Variable: Time taken to make a correct choice (milliseconds)

Time to correct selection was also positively impacted in our optimal design (LSM=3525.3ms, LCL=3260.6ms, UCL=3811.5ms), as compared to the two commercial labels we tested (LSM=8922.8ms, LCL=8105.9ms, UCL=9824.3ms and LSM=8260.4ms, LCL=7497.2ms, UCL=9101.2ms: p's<0.0001, see Figure 57).

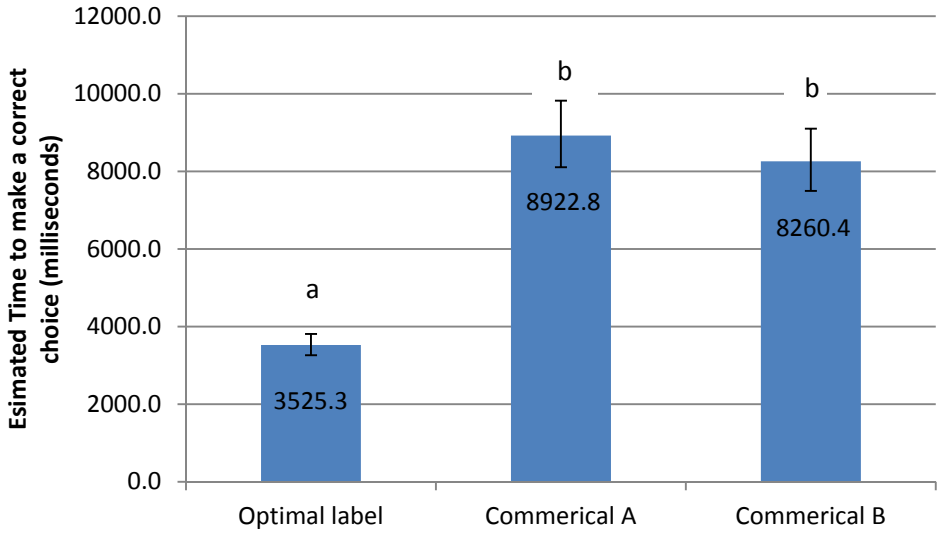


Figure 57. The effect of 'Grouped + Symbol presence + Color-coded' design on Time to make a correct choice, compared to commercial label designs: Estimated least square means (LSM) with estimated upper and lower limits. Differing letters indicate statistical significance at α=0.05.

5.4 Discussion

Like the change detection study**,** the sample population of this study was comprised of an experienced pool of healthcare providers (average experience years: 21, ranging from 0 to 51).

Results from both experiments bolster findings reported by Cai's study with

regard to what constitutes critical information (Table 20 and 33). Both sets of participants (n=86, change detection, n=89, forced choice task) reported expiration dating, sterility status, latex status and product name to be within the top 5 most critical pieces of information they use. Further, by sampling at conferences of a national, professional organization, it is not unreasonable to assume we were getting engaged providers from across the nation. In addition, the recommendations for improvement to labeling design were also very similar to what Cai suggested: i.e. noticeable texts employing bigger or bolder font, highlighting critical information in a single standard location (Table 23 and 36).

Our objective was to evaluate the effect of four design factors (Grouping, Boxing, Symbol and Color) on the three pieces of critical information during most stages of information processing (i.e. attention, perception, comprehension). It was expected that these design factors would enhance the information processing tasks of participants as indicated by a higher probability of correct choice and faster rates of correct choices.

Two design factors suggested a main effect on the probability of correct choices: Symbol ($p<0.0001$) and Boxing ($p=0.0101$). In analyzing the dependent variable, probability of correct choices, it was evident that symbol presence (LSM=97.7%) helped participants to make a higher rate of correct choices than symbol absence (LSM=94.4%, $p<0.0001$). This result suggests that symbols accompanying their supplementary text were helpful for participants to select correct devices. However, comprehension levels of stand-alone symbols were quite poor at the symbol-alone comprehension testing. By contrast, the boxed design (LSM=95.7%) resulted in a reduced probability of correct

choice, compared to the unboxed design (LSM=97.1%, p=0.0101).

When the time to make correct choices was analyzed, it clearly suggested that the three design treatments: grouping, symbol presence and color-coding, enabled participants to attend, perceive and comprehend the three pieces of critical information significantly faster, compared to other design treatments (α=0.05, Figures 53, 54 and 55). However, there was no evidence of a main effect of boxing on the time to make correct choices (p=0.4450).

The findings regarding boxing are interesting. Specifically, the presence of a box resulted in significantly reduced proportion of products chosen correctly, compared to those that were not boxed (LSM=95.7%, LCL=92.5%, UCL=97.5% vs. LSM=97.1%, LCL=94.9%, UCL=98.4%; p=0.0101). However, among correct choices, no benefit to the selection time was evident. By contrast, in the change detection experiment, changes were found faster in the boxed conditions (Figure 37), with designs that were ungrouped and boxed generating faster times than any of the other 4 combinations of boxing and grouping.

Perhaps most striking is the comparison of our theorized “optimal label” (grouping, symbol presence and color-coding), compared to two commercial labels (α=0.05, Figures 56 and 57). The commercial labels were created based on a synthesis of benchmarking studies comprised of 20 labels from manufacturers. Our optimal label increased the probability rate of correct choices and reduced the time to make a correct choice, when compared to the two commercial labels. Specifically, participants responded correctly in trials testing the optimal labels in approximately half the time, compared to the two commercial labels.

From a regulatory standpoint, required labeling information should be prominently placed with appropriate conspicuousness (as compared with other words, statements, designs, or devices, in the labeling) and should be likely to be read and understood by the ordinary individual under customary conditions of purchase and use (Federal Food, Drug and Cosmetic Act, Section 502). Our study provides evidence that improvements can be made with regard to correct selection and time to selection by leveraging design insights that have been recommended by healthcare providers tested here.

CHAPTER 6

CONCLUSIONS AND LIMITATIONS & FUTURE WORK

6.1 Conclusions

The efficacy of four design elements (Boxing, Grouping, Symbol and Color) was assessed on the three pieces of critical information for enhanced attention and comprehension. Two experiments were conducted to evaluate the effectiveness of the 16 mixed treatments (2 x 2 x 2 x 2) of these four design factors using the change detection and forced choice task methodologies.

During the change detection analysis, two elements emerged as having a consistently positive impact on time to detect changes: boxing (Figure 37) and color (Figure 38). That is, participants responded significantly faster to changes when color was present and when critical information was boxed. However, grouping of the information significantly affected response times in the presence of these other conditions. Responses to changes were significantly faster in the grouped condition (LSM=1747.4ms, LCL=1564.9ms, UCL=1951.6ms) than those not grouped (LSM=1843.7ms, LCL=1651.2ms, UCL=2059.2ms) when treatments were colored. By contrast, ungrouped treatments resulted in faster response times (LSM=1740.2ms, LCL=1558.5ms, UCL=1943.1ms) than grouped when boxes were present (LSM=1925.8ms, LCL=1724.2ms, UCL=2150.3ms).

These findings become more intriguing when coupled with those obtained from the forced choice experiment. Boxing proved to be a significant factor in making a correct choice, resulting in a reduced probability to correct selection (95.7% for boxed designs vs 97.1% for unboxed designs). Taken in total, this may suggest that visually

salient factors that are not imbedded within the message itself may actually subvert information processing.

By contrast, when design elements were imbedded within the message (i.e. color and symbol), the effect was clear and positive. When examining the four possible combinations of color and grouping, colored/grouped information (LSM=1747.4ms, LCL=1564.9ms, UCL=1951.6ms) outperformed all other treatments. Colored, ungrouped treatments (LSM=1843.7ms, LCL=1651.2ms, UCL=2059.2ms) resulted in significantly less time to detect changes than both the grouped (LSM=2260.5ms, LCL=2024.0ms, UCL=2524.6ms) and ungrouped treatments (LSM=2140.9ms, LCL=1917.3ms, UCL= 2391.1ms) with no color (see Figure 38). Symbol behaved similarly to color, and the symbol present, grouped treatment (LSM=1888.9ms, LCL=1691.2ms, UCL=2109.1ms) outperformed other symbol absent combinations: both ungrouped (LSM=2012.8ms, LCL=1802.2ms, UCL=2248.0ms) and grouped treatments (LSM=2091.7ms, LCL=1872.8ms, UCL=2336.1ms) without symbol presence (see Figure 39). Forced choice data also suggested clear benefits of these elements. Symbol presence positively influenced correct selection (97.7% when present versus 94.4% when absent; see Figure 52) and time to correct selection (3820.3ms when present vs 4848.4ms when absent; see Figure 54). A time to correct selection advantage was evident in colored treatments (3922.8ms for colored treatments vs 4722.8ms for non-colored treatments; see Figure 55).

In total, these findings lead us to theorize that visually salient design elements that are imbedded within the message (i.e. symbol and color) excel at attracting attention to the message being conveyed. Although visually salient features that are

not imbedded, but in close proximity (i.e. the box) provide advantage in early stages of information processing (i.e. attention), they have the potential to distract during the late stages (as evidenced by the reduced probability of correct choice).

Thus, the grouped, symbol-present and color-coded format enabled participants to choose a product that had latex, was sterile or was expired, at a significantly higher rate of correct selection and faster than the two commercial labels tested in this study.

In addition, the comprehension level of recognized symbols in the AAMI/ANSI/ISO 15223 was quite poor. Three out of 38 symbols tested in this study were critically confused and participants' responses were opposite of the intended, defined meaning of those symbols in the standard. The FDA rule currently proposed regarding the stand-alone graphical representation should be carefully taken into consideration before it is enacted.

6.2 Limitations & Future Study

Though boxing had a negative effect on correct choice (LSM=95.7%, LCL=92.5%, UCL=97.5% vs. LSM=97.1%, LCL=94.9%, UCL=98.4%; p=0.0101) in the forced choice experiment, it had a positive effect on time to detect change during change detection testing (see Figure 37). Along with the visual salient design not embedded within message, another assumed reason why this curious result occurred is that the multiple box design (see Figure 41) highlighting all pieces of critical information might not work as expected, if top-down processing predominated. As such, future work is recommended to test both a single box system to highlight targeted piece (s) of critical information and the multiple box system for comparison purposes.

In the change detection and forced choice task experiments, locations of change

detection and forced choice were randomized to mitigate their effects. Both experiments suggested that there was evidence of a significant effect of location on the dependent variables: time to detect change and time to correct choice. Previous research (Bix et al., 2010) reported the effect of locations on detection time. Thus, it is recommended to analyze this research data so as to see behaviors of participants to detect change at different image locations.

The change detection and forced choice task experiments were conducted on a computer monitor to simulate a context of a medical device being used. There could be some difference of attentional behaviors of healthcare professionals between this simulated environment and a real context in the use of medical devices. In more realistic environments, real context research is recommended to assess the effect of Grouping, Symbol and Color coding.

In our symbol comprehension study, an open-ended test was used to assess comprehension levels of medical device symbols. Participants were asked to write the meaning of medical device symbols on a response form. Some literature (Vukelich & Whitaker, 1993 and Wolff & Wogalter, 1998) suggests that the presence of context (depicting the probable environment where a symbol would be seen) enhances the level of symbol comprehension. It would be worthwhile to evaluate symbol comprehension in a context-based test form (e.g. symbols being embedded on a real medical device label) in future research. In addition, participants who were recruited for our symbol comprehension study were generalists (e.g. surgical technologists, registered nurses, etc.) in the healthcare industry. Twenty-two out of the tested 38 symbols were included in the FDA guidance: Use of symbols on labels and in labeling In-Vitro

Diagnostic devices intended for professional use (2004). Some specialized symbols (e.g. In Vitro Diagnostic medical device, Lower limit of temperature, Upper limit temperature, Temperature limitation, etc.) used for In-Vitro Diagnostic devices may not be commonly used in the environments where our participants work. That said, results were similar to those reported by Hermans, et al. (2011) who did tailor their test population to a specific environment and also utilized context testing.

APPENDICS

APPENDIX 1. Proposed Rules of FDA on medical device labeling

1. "Unique Device Identification (UDI) System"

In July 2012, the US Food and Drug Administration (FDA) proposed a rule requiring a Unique Device Identifier (UDI) for the vast majority of medical devices (FDA, UDI Proposed Rule, 2012), and a final rule of the UDI was published in the Federal Register, in September, 2013 (FDA, UDI Final Rule, 2013). Its final rule requires a device identifier and a production identifier to be provided in an easily readable, plain-text version and in a form that uses Advanced Identification Data Capture (AIDC) technology on the label and package of a medical device (FDA, UDI Final rule, 2013).

- Device identifier: The specific version or model of a device and the labeler of that device
- Production identifier: One or more of the followings should be present on the label of a device:
  - ✓ The lot or batch within which a device was manufactured
  - ✓ The serial number of a specific device
  - ✓ The expiration date of a specific device
    - o Date format: YYYY-MM-DD (e.g., 2013-09-30)
  - ✓ The date a specific devices was manufactured
  - ✓ The distinct identification code required by 21 CFR 1271. 290 (c) for a human cell tissue, or cellular and tissue-based products (HCT/P) regulated as a device.

For certain categories of medical devices which may be used for an extended periods of time or may become separated from their labeling (examples: implantable devices, multiple use devices and devices sterilized before each use or stand-alone software), direct marking of the UDI on the device itself is required (FDA, UDI Final rule, 2013).

FDA expects that several important public health benefits will be generated through adequate identification of medical devices at the time of distribution and use (FDA, UDI Proposed rule, 2012). The key benefits anticipated to be achieved with the implementation of a UDI system are listed in the following table (FDA, UDI, Proposed rule, 2012).

Table 37. Key benefits through UDI implementation

Benefits	Details
Reduce Medical Errors	The presence of a UDI that is linked to device information in the Global Unique Device Identification Database (GUDID) database will facilitate rapid and accurate identification of a device, thereby removing a cause of confusion that can lead to inappropriate use of a device (e.g., confusion as to whether a device is packaged as sterile, or failure to recognize that a device is the subject of a recall or enforcement action).
Simplify the Integration of Device Use Information Into Data Systems	UDIs, particularly when provided through AIDC technology, would allow rapid and accurate data acquisition, recording, and retrieval.
Provide for More Rapid Identification of Medical Devices With Adverse Events	The inclusion of UDIs in adverse event reports would lead to greater accuracy in reporting, by eliminating uncertainty concerning the identity of the device that is the subject of a report.
Provide for More Rapid Development of Solutions to Reported Problems	The inclusion of UDIs in adverse event reports would allow manufacturers and FDA to more rapidly review, aggregate, and analyze related reports regarding a particular device.
Provide for More Rapid, More Efficient Resolution of Device Recalls	Delays in identifying recalled devices can result in the continued use of those devices on patients and involves an increased risk for patient harm. A device labeled with a UDI can be identified rapidly and with great precision and the UDI, particularly when combined with AIDC technology, will hasten the identification of devices that are the subject of a recall.

Table 37. (Cont'd)	
Better-Focused and More Effective FDA Safety Communication	By citing UDIs, FDA would be able to more precisely focus safety alerts, public health notifications, or other communications, eliminating confusion with similar devices and allowing more rapid responsive action.
Provide an Easily-Accessible Source of Definitive Device Identification Information	The inclusion of device identifiers could allow the document to focus on its important core messages without the distraction of greater complexity, while a reader who wants those additional details could use the UDI to obtain information from the GUDID.
Standard Format for Dates Provided on a Device Label or Package	The rule would also contribute to improved identification of medical devices, and at the same time, better ensure the safe use of devices, by requiring dates on medical device labels to conform to a standard format to ensure dates are unambiguous and clearly understood by device users.

2. “Use of Certain Symbols in Labeling” to allow for the inclusion of stand-alone graphical representations of information, or symbols

The “Use of Certain Symbols in Labeling”, another proposed rule, would allow the inclusion of stand-alone graphical representations of information, accompanied by a symbols glossary, provided they are recognized standards, and the use of “Rx” only without accompanying explanation text (FDA, Use of Certain Symbols, Proposed rule, 2013). Based on current, general labeling requirements (CFR Title 21, Part 801), graphics, pictures or symbols have to be accompanied by explanatory English text adjacent to those graphical representations except for In Vitro Diagnostic Devices (IVD) intended for professional use. The intention of the proposed rule is to make labeling more user-friendly by replacing small, difficult-to-read text with pictorial information and to harmonize the labeling requirements of U.S. and other regulatory bodies (FDA, Use of Certain Symbols, Proposed rule, 2013). Incongruence in European and U.S. requirements regarding symbol representation on medical device labeling is a recognized issue. In Europe, stand-alone graphical representations are used for medical sold in multiple countries in order to avoid multiple languages on their label. If implemented, this regulatory difference would be harmonized to avoid the development of different labels of a medical device which may be sold in US and Europe (FDA, Use of Certain Symbols, Proposed rule, 2013).

APPENDIX 2. Misbranding (specified by section 502 of the Federal, Food, Drug and Cosmetic Act)

Table 38. Misbranding items		
No.	**Contents**	**Remarks**
1	False or misleading label	**Labeling-related**
2	Package form; contents of label	**Labeling-related**
3	Prominence of information on label	**Labeling-related**
4	Designation of drugs or devices by established Names	**Labeling-related**
5	Directions for use and warnings on label	**Labeling-related**
6	Representations as recognized drug; packing and labeling; inconsistent requirements for designation of drug	drug-related
7	Deteriorative drugs; packing and labeling	drug-related
8	Drug; misleading container; imitation; offer for sale under another name	drug-related
9	Health-endangering when used as prescribed	**Labeling-related**
10	Color additives; packing and labeling	**Labeling-related**
11	Prescription drug advertisements: established name; quantitative formula; side effects, contraindications, and effectiveness; prior approval; false advertising; labeling; construction of the Convention on Psychotropic Substances	drug-related
12	Drugs or devices from nonregistered establishments	**Labeling-related**
13	Packaging or labeling of drugs in violation of Regulations	drug-related
14	Restricted devices using false or misleading advertising or used in violation of regulations	
15	Restricted devices not carrying requisite accompanying statements in advertisements and other descriptive printed matter	
16	Devices subject to performance standards not bearing requisite labeling	**Labeling-related**
17	Devices for which there has been a failure or refusal to give required notification or to furnish required material or information	**Labeling-related**
18	Identification of manufacturer	**Labeling-related**
19	Reprocessed single-use devices	
20	New animal drugs	drug-related
21	Nonprescription drugs	drug-related
22	Drugs subject to approved risk evaluation and mitigation strategy	drug-related
23	Post-market studies and clinical trials; new safety information in labeling	drug-related

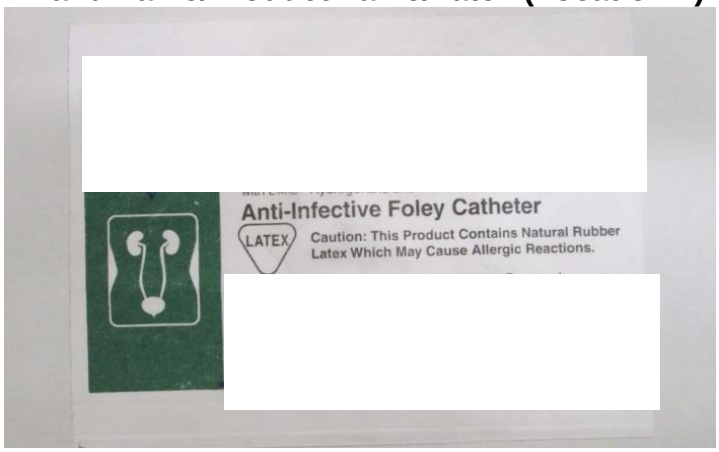
APPENDIX 3. Latex glove manufacturing process

Table 39. Latex glove manufacturing process (Zalglaniczny, 2001; Yunginger, 1998)	
Process	**Description**
Natural rubber latex harvesting	Natural-latex containing protein is harvested from *Hevea brasilienis* rubber tree.
Collection with ammonia	Autocoagulation of natural latex is prevented by the addition of ammonia.
Concentration from 30% - 60% solid	Natural latex is centrifuged and concentrated from 30% to 60% solids. Removal of serum phase reduces the concentration of water soluble proteins.
Compounding	Processing and attributes of the finished device depend on the addition of many chemicals to the natural latex (compounding). Significant Type IV allergens include the accelerators and antioxidants.
Brush or ultrasonic former cleaning	Porcelain formers attached to a continuous chain are cleaned to remove debris to a previous cycle.
Coagulant dipping	Formers are dipped in an emulsion to apply corn starch as a releasing agent and a compound that coagulates liquid natural latex on contact.
Agent drying	Releasing agent and coagulant are oven-dried.
Latex dipping	Formers dip into natural latex and a uniform film is deposited.
Oven heating	The coagulant and heat convert the natural latex from liquid to solid.
Bead rolling	Rotating brushes contact the rotating formers and a cuff is rolled onto the glove.
Leaching in water tank	Formers pass through water baths to remove water-soluble protein and excess additives.
Vulcanization in oven	Cross-linking of the polyisoprene polymers is catalyzed by heat and requires an accelerator.
Application of corn starch power	Corn starch is applied as slurry to the outer surface of the natural rubber latex as a detacking agent. Residual rubber proteins may elute from the gloves at this point and bind to the corn starch particles.
Stripping	The gloves are stripped from the porcelain formers.

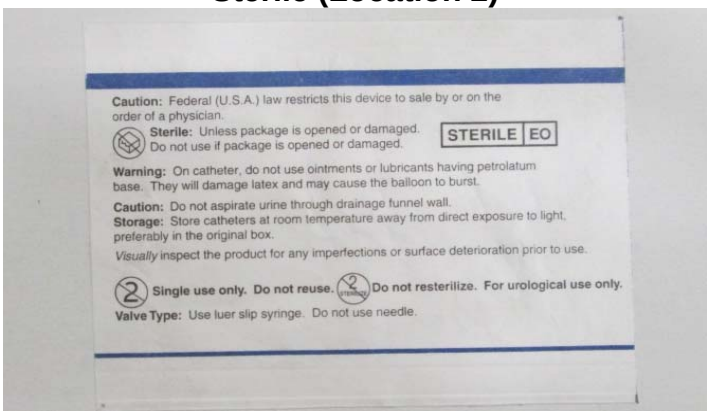
APPENDIX 4. Stimulus materials for Legibility test

Brand A

Brand name/Product name/Latex (Location 1)



Sterile (Location 2)



Sub-product name/Expiration dating (Location 4)

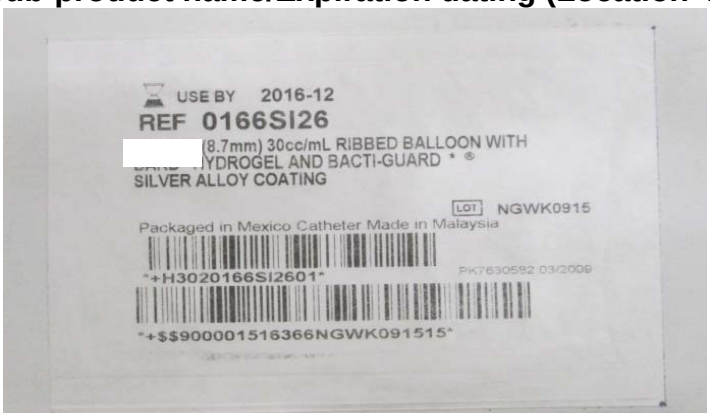


Figure 58. Legibility stimulus materials for Brand A

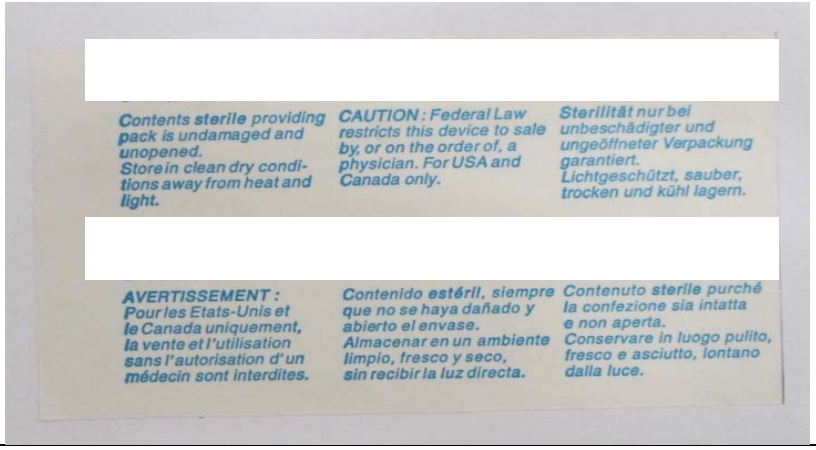
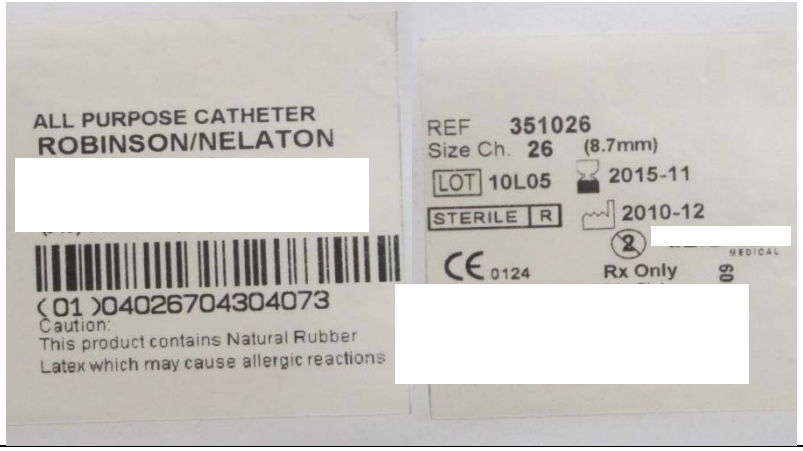
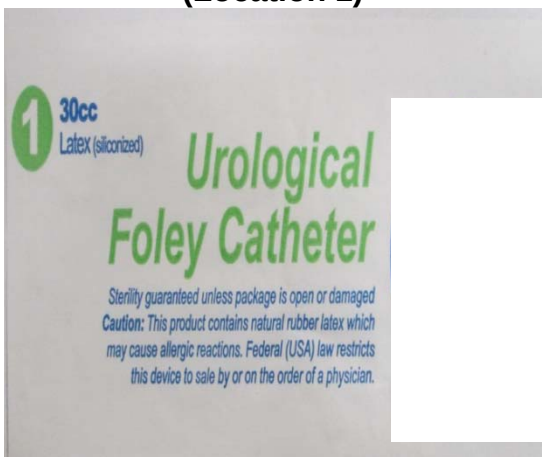
Brand B
Brand name/Sterile(text) (Location 1) 
Product name/Sub-product name/Latex/Sterile(symbol)/Expiration dating (Location 4) 

Figure 59. Legibility stimulus materials for Brand B

Brand C

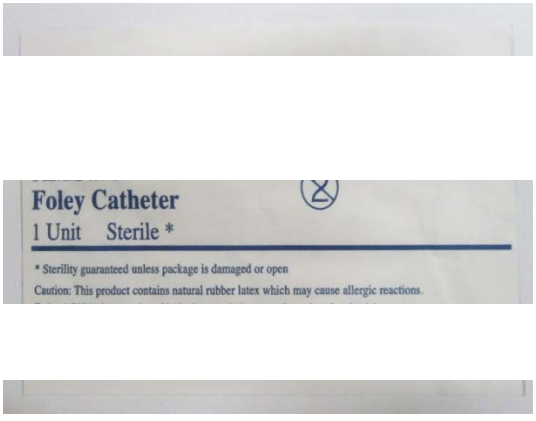
Brand name/Product name/Sterile/Latex (Location 1)



Sub-product name/Expiration dating (Location 4)

Brand D

Brand name/Product name/Sterile/Latex (Location 1)



Sub-product name/Expiration dating (Location 4)

Figure 60. Legibility stimulus materials for Brand C and D

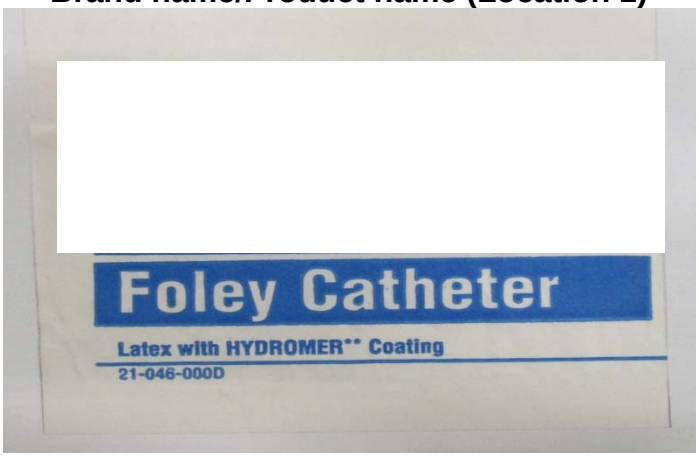
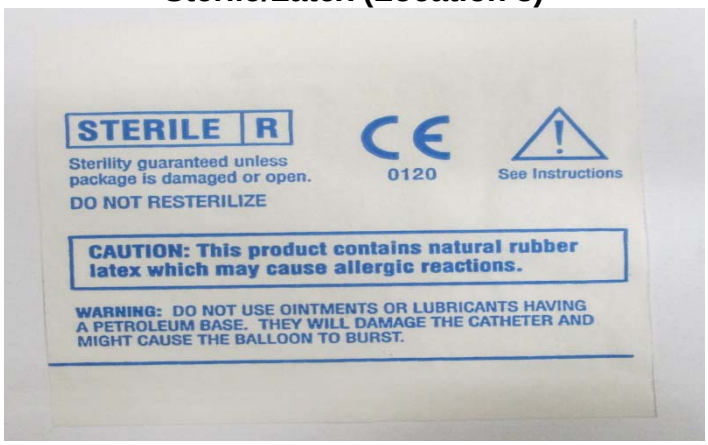
Brand E
Brand name/Product name (Location 1) 
Sterile/Latex (Location 3) 
Sub-product name/Expiration dating (Location 4) 

Figure 61. Legibility stimulus materials for Brand E

Brand F

Brand name/Product name (Location 1)

Sterile (Symbol)/Latex (Location 4)

Sub-product name/Expiration dating (Front side)

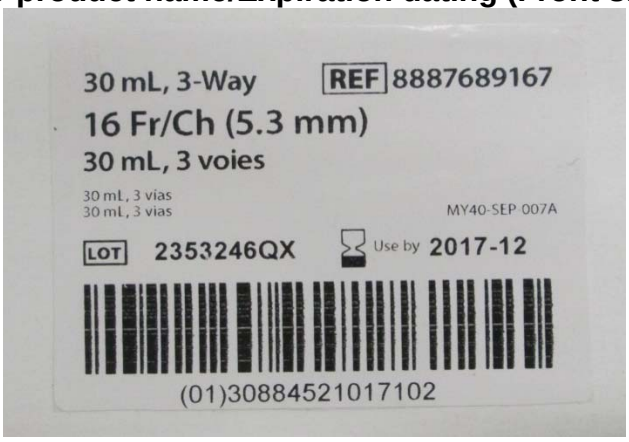


Figure 62. Legibility stimulus materials for Brand F

APPENDIX 5. Data collection sheet: Legibility test

Research Questionnaire/Data collection Form

Legibility of Medical Device Labels

Subject #: _____

A. Data collection sheet

Subject #: ☐ Gender: ☐ Age: ☐

Health Literacy: ☐ Color differentiation ability: ☐

Inside Light Level: ☐ Ambient Light Level: ☐ Visual Acuity: ☐

B. Questionnaire

1. **What is your gender?**
   Female _____ Male_____

2. **What is your age?**
   _____

3. **What is your ethnicity?**

   American Indian/Alaskan Native_____, Asian or Pacific Islander_____
   Black, non-Hispanic _____, Hispanic _____
   White, non-Hispanic_____, Other _____

4. **What is the highest level of education you achieved?**
   Associate's Degree _____, Bachelor's Degree _____
   Master's Degree _____, Doctor Degree _____
   Other _____

5. **What is your native language?**
   _____

Thanks for your effort to fill out this questionnaire form above. The next page will be filled out by the researcher of this study.

Table 40. Legibility data sheet

Run order	Test Stimulus	Labeling Information	Distance (Wall to Easel)	Required Degrees of Rotation
1				
2				
3				
4				
5				
6				
7				
8				
9				
10				
11				
12				
13				
14				
15				
16				
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21				
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23				
24				
25				
26				
27				
28				
29				
30				

APPENDIX 6. Data collection sheet: Comprehension test

Data Collection Sheet

Comprehension level on medical device symbols

Subject #: Gender: Age:

Health Literacy: Color differentiation ability:

Visual Acuity:

Instructions:

This study is intended to evaluate your comprehension level on medical device symbols used for commercially available medical devices. Please view the medical device symbols presented in the following table, and fill in the box of "Answer" with a meaning of each symbol which you think. If you are not able to assign a meaning of a symbol (s), you can simply write "Don't know" in the answer box. But, it is highly recommended to write whatever you think each symbol means.

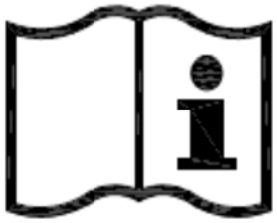
Symbol 1:  Answer:	Symbol 2:  Answer:
Symbol 3:  Answer:	Symbol 4:  Answer:

Figure 63. Medical device symbols

Figure 63. (Cont'd)

Symbol 5:  Answer:	Symbol 6:  Answer:
Symbol 7:  Answer:	Symbol 8:  Answer:
Symbol 9:  Answer:	Symbol 10:  Answer:

Figure 63. (Cont'd)

Symbol 11:  Answer:	Symbol 12:  Answer:
Symbol 13:  Answer:	Symbol 14:  Answer:
Symbol 15:  Answer:	Symbol 16:  Answer:

Figure 63. (Cont'd)

Symbol 17:  Answer:	Symbol 18:  Answer:
Symbol 19:  Answer:	Symbol 20:  Answer:
Symbol 21:  Answer:	Symbol 22:  Answer:
Symbol 23:  Answer:	Symbol 24:  Answer:

Figure 63. (Cont'd)

Symbol 25:  Answer:	Symbol 26:  Answer:
Symbol 27:  Answer:	Symbol 28:  Answer:
Symbol 29:  Answer:	Symbol 30:  Answer:

Figure 63. (Cont'd)

Symbol 31:

Answer:

Symbol 32:

Answer:

Symbol 33:

Answer:

Symbol 34:

Answer:

Symbol 35:

Answer:

Symbol 36:

Answer

Figure 63. (Cont'd)

Symbol 37:  Answer	Symbol 38:  Answer
Symbol 39:  Answer	Symbol 40:  Answer:
Symbol 41:  Answer	

APPENDIX 7. Research questionnaire form: Change Detection/Forced Choice Task tests

Research Questionnaire Form

Subject #: _____

A. Demographic Survey

1. **What is your gender?**
   Female _____ Male_____

2. **What is your age?**
   _____

3. **What is your ethnicity?**
   American Indian/Alaskan Native_____, Asian or Pacific Islander_____
   Black, non-Hispanic_____, Hispanic _____
   White, non-Hispanic _____, Other _____

4. **What is the highest level of education you achieved?**
   Associate's Degree _____, Bachelor's Degree _____
   Advanced Practice Nurse certificate _____, Master's Degree _____
   Doctor Degree_____, Other _____

5. **What is your native language?**
   _____

B. Job-related Survey

6. **What is your current employment setting?**

   Acute Care Hospital _____, Physician's office _____
   Ambulatory/Day Surgery Center_____
   Nursing home/long-term care facility _____
   Public/community health _____
   Student _____, Other _____

7. **What is your position and role in your employment?**

_____

8. **How many years have you been working in the healthcare industry?**

_____

9. **What labeling information do you care about on packages of medical devices? (Mark at least 5 items)**

1) Brand name _____ 2) Product name _____

3) Latex _____ 4) Sterile _____

5) Use instruction_____ 6) Expiration dating _____

7) Serial # _____ 8) Batch code _____

9) Manufacturer name _____ 10) Do not reuse _____

11) Do not resterilize _____ 12) Date of manufacture _____

13) Do not use if package is opened or damaged _____

10. **What is the top 4 labeling information you really care about before using medical devices among the marked items at question 9?**

1) _____
2) _____
3) _____
4) _____

11. **What problems do you have to capture the labeling information of medical device packages easily? (e.g. small font size, no color contrast, no color coding, no standard location for critical information, etc.)**

1) _____
2) _____
3) _____
4) _____
5) _____

12. What medical errors have you experienced because of a labeling issue(s) of medical devices?

1) _____
2) _____
3) _____
4) _____
5) _____

13. What would be your recommendations to resolve a problem(s) you have in capturing the labeling information of medical device packages? (e.g. Bigger font size, color contrast, color coding, standard location for critical information, etc.)

_____
_____
_____
_____
_____

APPENDIX 8. Consent form: Legibility test

Research Participant Information and Consent Form

You are being asked to participate in a research study. Researchers are required to provide a consent form to inform you about the research study, to convey that participation is voluntary, to explain risks and benefits of participation, and to empower you to make an informed decision. You should feel free to ask the researchers any questions you may have.

Study Title: Legibility measurement of medical device labels (Experiment 1 for the project of "Assessing the critical information on existing commercial labeling of indwelling, urinary catheters to develop new designs for enhanced attention capture and comprehension)
Researcher and Title: Laura Bix / Associate Professor
Department and Institution: School of Packaging, MSU / 153 Packaging Building East Lansing MI 48824 / E-mail: bixlaura@msu.edu, Phone: 517-355-4556
Teleflex and CR Bard have provided an in-kind donation of the products being tested. Beyond that, this research is funded through internal monies.

1. PURPOSE OF RESEARCH

You have been selected as a possible participant in this study because you may meet the following criteria:

- Be over 18 years of age
- Not be legally blind
- Have transportation to the School of Packaging at MSU, where the study will take place

From this study, the researchers hope to evaluate the relative legibility of label information for medical devices using an instrument called the Lockhart Legibility Instrument (LLI)

Your participation in this study will take no longer than 30 minutes. In the entire study, 100 people are being asked to participate.

2. WHAT YOU WILL DO

As part of this research, we will record your gender, ethnicity, educational background, and age. We will also ask you to read several words aloud as a measure of your ability to read medical labels. We will ask you to read a series of numbers made of colored dots; this will test your ability to see color. We will also ask you to read the smallest line of a card consisting of a series of lines of text as a measure of your visual acuity (20/20, 20/30, etc.).

After your color blindness and visual acuity are tested, you will be asked to read several medical device labels using the LLI instrument. This instrument is a tool to measure the relative ease with which different information on labels can be read.

- We will ask you to read a series of labels being placed inside the LLI. Look into the gray box through the screen on the front. While you look through the screen, rotate the hand wheel of the LLI on the right hand until you easily read the entire phrase that appears on the label. A researcher will record the value from the LLI. Once this is done, please rotate the hand wheel back to the starting position, which will make the screen dark again.
- This will be repeated for a total of 32 trials.

This consent form was approved by a Michigan State University Institutional Review Board.
Approved 08/08/2013 - valid through - 08/7/2014. This version supersedes all previous versions. IRB # 13-698

3. POTENTIAL BENEFITS

You will not directly benefit from your participation in this study. However, your participation in this study may contribute to designing labels for medical devices that are easier for people to use

4. POTENTIAL RISKS

There are no foreseeable risks associated with participation in this study. During a portion of the testing, we will ask you to read a series of words aloud. It is possible that that you may not be familiar with these words and that this may embarrass you. To minimize the impact of this, all testing will be conducted in private, with only members of the research team present. In the event that you are uncomfortable with any of the tasks, you may elect to skip a portion of the study, or discontinue altogether.

5. PRIVACY AND CONFIDENTIALITY

The data for this project will be kept confidential. All information will be tied to a subject number; collected information will not be identified by name and your confidentiality will be maintained to the maximum extent of the law. Information retrieved during this entire study will be protected on a password protected computer or in a locked file cabinet on the campus of Michigan State University for a minimum of three years after the close of the project.

Only the appointed researchers and the Institutional Review Board will have access to the research data. Within these restrictions, results of the study will be made available to you at your request.

The results of this study may be published or presented at professional meetings, but the identities of all research participants will remain anonymous.

6. YOUR RIGHTS TO PARTICIPATE, SAY NO, OR WITHDRAW

Your participation in this study is voluntary. As such, you may choose not to participate at all, or you may refuse to participate in certain procedures or to answer certain questions, or discontinue your participation at any time without consequence. Whether you choose to participate or not will have no affect on your grade or evaluation.

7. COSTS AND COMPENSATION FOR BEING IN THE STUDY

In exchange for your participation in this study, you will receive 4 points extra credit in PKG 101, PKG 330. To be eligible for this extra credit, you must have contacted the research team on or before October 15, 2013. Even if you do not complete some portions of the study or choose to withdraw from this study, you will still receive the extra credit.

8. ALTERNATIVE OPTIONS

This consent form was approved by a Michigan State University Institutional Review Board.
Approved 08/08/2013 - valid through - 08/7/2014. This version supersedes all previous versions. IRB # 13-698

- If you are interested in getting the extra credit but do not wish to participate in this research, please see your instructor for an alternative assignment.

9. CONTACT INFORMATION

If you have concerns or questions about this study, such as scientific issues, how to do any part of it, or to report an injury, please contact the researcher (Laura Bix 517-355-4556; 153 Packaging Building East Lansing, MI 48824 bixlaura@msu.edu).

If you have questions or concerns about your role and rights as a research participant, would like to obtain information or offer input, or would like to register a complaint about this study, you may contact, anonymously if you wish, the Michigan State University's Human Research Protection Program at 517-355-2180, Fax 517-432-4503, or e-mail irb@msu.edu or regular mail at Olds Hall, 408 West Circle Drive #207, MSU, East Lansing, MI 48824.

10. DOCUMENTATION OF INFORMED CONSENT.

Your signature below means that you voluntarily agree to participate in this research study.

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Signature Date

You will be given a copy of this form to keep.

APPENDIX 9. Consent form: Change Detection/Comprehension tests

Research Participant Information and Consent Form

You are being asked to participate in a research study. Researchers are required to provide a consent form to inform you about the research study, to convey that participation is voluntary, to explain risks and benefits of participation, and to empower you to make an informed decision. You should feel free to ask the researchers any questions you may have.

Study Title: Change Detection to test the noticeability and comprehension of critical labeling information of a medical device (Experiment 2 for the project of "Assessing the critical information on existing commercial labeling of indwelling, urinary catheters to develop new designs for enhanced attention capture and comprehension)
Researcher and Title: Laura Bix / Associate Professor
Department and Institution: School of Packaging, MSU / 153 Packaging Building East Lansing MI 48824 / E-mail: bixlaura@msu.edu, Phone: 517-355-4556
Teleflex and CR Bard have provided an in-kind donation of the products being tested.

1. PURPOSE OF RESEARCH

You have been selected as a possible participant in this study because you may meet the following criteria:

- Have NO HISTORY OF SEIZURE
- Be over 18 years of age
- Not be legally blind
- Be a healthcare professional, nursing or surgical technology student

From this study, the researchers hope to investigate the design effects of medical device labels using change detection methodology and to evaluate the comprehension level of medical device symbols.

Your participation in this study will take no longer than 1 1/2 hours. In the entire study, 60 people are being asked to participate.

2. WHAT YOU WILL DO

As part of this research, we will record your gender, ethnicity, educational background, and age. We will ask you some questions about your history as a healthcare professional. Specifically, we will ask questions regarding medication errors that you have been involved with that may be uncomfortable for you to discuss or recall.

We will also ask you to read several words aloud as a measure of your ability to read medical labels. We will ask you to read a series of numbers made of colored dots; this will test your ability to see color. We will also ask you to read the smallest line of a card consisting of a series of lines of text as a measure of your visual acuity (20/20, 20/30, etc.).

After the color blindness and visual acuity are tested, you will be asked to view several images of medical device labels on a computer screen.

- A test image continuously alternates with the same image, slightly altered

with a gray (blank) screen. This image-blank-test-blank will loop, providing a "flickering" at the place of alteration, until you press the space bar, indicating that you have found the change. You will then be asked to click on the place where you saw the flickering of the image. If you cannot find the change within 1 minute, the software will move testing to the next trial. This process will be repeated for a total of 96 trials. If you become tired during testing and need a break, just wait until you have finished a trial and don't move on to the next one. The research team can help you with this if you have any questions.

After completing the change detection comprehension testing, you will be provided with a printed test sheet with several medical device symbols. You will be asked to write down what you believe each of the symbols means.

3. POTENTIAL BENEFITS

You will not directly benefit from your participation in this study. However, the study does carry benefit to society. Using the data generated in this study, it is our hope that we can design medical device labels that are easier and more efficient for healthcare providers.

4. POTENTIAL RISKS

There are limited risks associated with participation in this study. We will ask you to read aloud a series of words. It is possible that you may not be familiar with these words and this will be embarrassing to you.

There is a possible risk of seizure that is associated with viewing flashing images; as a result, if you have a history of seizure, you are not eligible to participate.

If you are injured as a result of your participation in this research project, researchers from Michigan State University will assist you in obtaining emergency care, if necessary, for your research-related injuries. If you have insurance for medical care, your insurance carrier will be billed in the ordinary manner. As with any medical insurance, any costs that are not covered or in excess of what are paid by your insurance, including deductibles, will be your responsibility.

The University's policy is not to provide financial compensation for lost wages, disability, pain or discomfort unless required by law to do so. This does not mean that you are giving up any legal rights you may have.

In the event that you are uncomfortable with any of the tasks, you may elect to skip a portion of the study, or discontinue altogether.

5. PRIVACY AND CONFIDENTIALITY

The data for this project will be kept confidential. All information will be tied to a subject number; collected information will not be identified by name and your confidentiality will be maintained to

the maximum extent of the law. Information retrieved during this entire study will be protected on a password protected computer or in a locked file cabinet on the campus of Michigan State University for a minimum of three years after the close of the project.

Only the appointed researchers and the Institutional Review Board will have access to the research data. Within these restrictions, results of the study will be made available to you at your request.

The results of this study may be published or presented at professional meetings, but the identities of all research participants will remain anonymous.

6. YOUR RIGHTS TO PARTICIPATE, SAY NO, OR WITHDRAW

Your participation in this study is voluntary. As such, you may choose not to participate at all, or you may refuse to participate in certain procedures or to answer certain questions, or discontinue your participation at any time without consequence. Whether you choose to participate or not will have no affect on your grade or evaluation.

7. COSTS AND COMPENSATION FOR BEING IN THE STUDY

You will receive $30 in exchange for your participation in this study. Even if you do not complete some portions of the study or choose to withdraw from this study altogether, you will still receive the $30

8. CONTACT INFORMATION

If you have concerns or questions about this study, such as scientific issues, how to do any part of it, or to report an injury, please contact the researcher (Laura Bix 517-355-4556; 153 Packaging Building East Lansing, MI 48824 bixlaura@msu.edu).

If you have questions or concerns about your role and rights as a research participant, would like to obtain information or offer input, or would like to register a complaint about this study, you may contact, anonymously if you wish, the Michigan State University's Human Research Protection Program at 517-355-2180, Fax 517-432-4503, or e-mail irb@msu.edu or regular mail at Olds Hall, 408 West Circle Drive #207, MSU, East Lansing, MI 48824.

9. DOCUMENTATION OF INFORMED CONSENT.

Your signature below means that you voluntarily agree to participate in this research study.

---------- ----------

Signature Date

You will be given a copy of this form to keep.

This consent form was approved by a Michigan State University Institutional Review Board.
Approved 1/30/2014 - valid through - 08/07/2014. This version supersedes all previous versions. IRB # 13-698

APPENDIX 10. Consent form: Forced Choice Task test

Research Participant Information and Consent Form

You are being asked to participate in a research study. Researchers are required to provide a consent form to inform you about the research study, to convey that participation is voluntary, to explain risks and benefits of participation, and to empower you to make an informed decision. You should feel free to ask the researchers any questions you may have.

Study Title: Investigating attention to and selection of medical devices with varied labels (Experiment 3 for the project of "Assessing the critical information on existing commercial labeling of indwelling, urinary catheters to develop new designs for enhanced attention capture and comprehension)
Researcher and Title: Laura Bix / Associate Professor
Department and Institution: School of Packaging, MSU / 153 Packaging Building East Lansing MI 48824 / E-mail: bixlaura@msu.edu, Phone: 517-355-4556
Teleflex and CR Bard have provided an in-kind donation of the products being tested.

1. PURPOSE OF RESEARCH

You have been selected as a possible participant in this study because you may meet the following criteria:

- Be over 18 years of age
- Not be legally blind
- Be a healthcare professional, nursing or surgical technology student

From this study, the researchers hope to evaluate how design features of medical device labels influence information processing using eye tracking during a forced choice task.

Your participation in this study will take no longer than 1 hour. In the entire study, 80 people are being asked to participate.

2. WHAT YOU WILL DO

As part of this research, we will record your gender, ethnicity, educational background, and age. We will ask you some questions about your history as a healthcare professional. Specifically, we will ask questions regarding medication errors that you have been involved with that may be uncomfortable for you to discuss or recall.

We will also ask you to read several words aloud as a measure of your ability to read medical labels. We will ask you to read a series of numbers made of colored dots; this will test your ability to see color. We will also ask you to read the smallest line of a card consisting of a series of lines of text as a measure of your visual acuity (20/20, 20/30, etc.).

Experiment Procedure

You will see a series of trials on a computer screen which will consist of two labels that are identical with the exception of one aspect of the critical labeling information (e.g. one with latex, the other without latex). You will be instructed to select one of the labels (e.g. select the product which is latex free) as quickly as possible by depressing either 1 or 7 on a keypad that you

will be provided. The labels of the products are organized in different ways so that we can learn about how graphic design can assist/hinder healthcare professionals select the appropriate product as quickly as possible.

This process will be repeated for a total of 54 trials. If you become tired during testing and need a break, just wait until you have finished a trial and don't move on to the next one. The research team can help you with this if you have any questions

3. POTENTIAL BENEFITS

You will not directly benefit from your participation in this study. However, the study does carry benefit to society. Using the data generated in this study, it is our hope that we can design medical device labels that are easier for healthcare providers to use and that will facilitate correct choices in chaotic environments.

4. POTENTIAL RISKS

There are limited risks associated with participation in this study. We will ask you to read aloud a series of words. It is possible that you may not be familiar with these words and this will be embarrassing to you.

We will also ask you to read a series of words aloud. It is possible that you may not be familiar with some of these words, and this may be embarrassing to you. In the event that you are uncomfortable with any of the tasks, you may elect to skip a portion of the study, or discontinue altogether.

If you are injured as a result of your participation in this research project, researchers from Michigan State University will assist you in obtaining emergency care, if necessary, for your research-related injuries. If you have insurance for medical care, your insurance carrier will be billed in the ordinary manner. As with any medical insurance, any costs that are not covered or in excess of what are paid by your insurance, including deductibles, will be your responsibility.

The University's policy is not to provide financial compensation for lost wages, disability, pain or discomfort unless required by law to do so. This does not mean that you are giving up any legal rights you may have.

5. PRIVACY AND CONFIDENTIALITY

The data for this project will be kept confidential. All information will be tied to a subject number; collected information will not be identified by name and your confidentiality will be maintained to the maximum extent of the law. Information retrieved during this entire study will be protected on a password protected computer or in a locked file cabinet on the campus of Michigan State University for a minimum of three years after the close of the project.

Only the appointed researchers and the Institutional Review Board will have access to the research data. Within these restrictions, results of the study will be made available to you at your request.

The results of this study may be published or presented at professional meetings, but the identities of all research participants will remain anonymous.

6. YOUR RIGHTS TO PARTICIPATE, SAY NO, OR WITHDRAW

Your participation in this study is voluntary. As such, you may choose not to participate at all, or you may refuse to participate in certain procedures or to answer certain questions, or discontinue your participation at any time without consequence. Whether you choose to participate or not will have no affect on your grade or evaluation.

7. COSTS AND COMPENSATION FOR BEING IN THE STUDY

You will receive $30 in exchange for your participation in this study. Even if you do not complete some portions of the study or choose to withdraw from this study altogether, you will still receive the $30

8. CONTACT INFORMATION

If you have concerns or questions about this study, such as scientific issues, how to do any part of it, or to report an injury, please contact the researcher (Laura Bix 517-355-4556; 153 Packaging Building East Lansing, MI 48824 bixlaura@msu.edu).

If you have questions or concerns about your role and rights as a research participant, would like to obtain information or offer input, or would like to register a complaint about this study, you may contact, anonymously if you wish, the Michigan State University's Human Research Protection Program at 517-355-2180, Fax 517-432-4503, or e-mail irb@msu.edu or regular mail at Olds Hall, 408 West Circle Drive #207, MSU, East Lansing, MI 48824.

9. DOCUMENTATION OF INFORMED CONSENT.

Your signature below means that you voluntarily agree to participate in this research study.

---------- ----------

Signature Date

You will be given a copy of this form to keep.

This consent form was approved by a Michigan State University Institutional Review Board.
Approved 1/30/2014 - valid through - 08/07/2014. This version supersedes all previous versions. IRB # 13-698

APPENDIX 11. Recruitment flyer: Legibility test

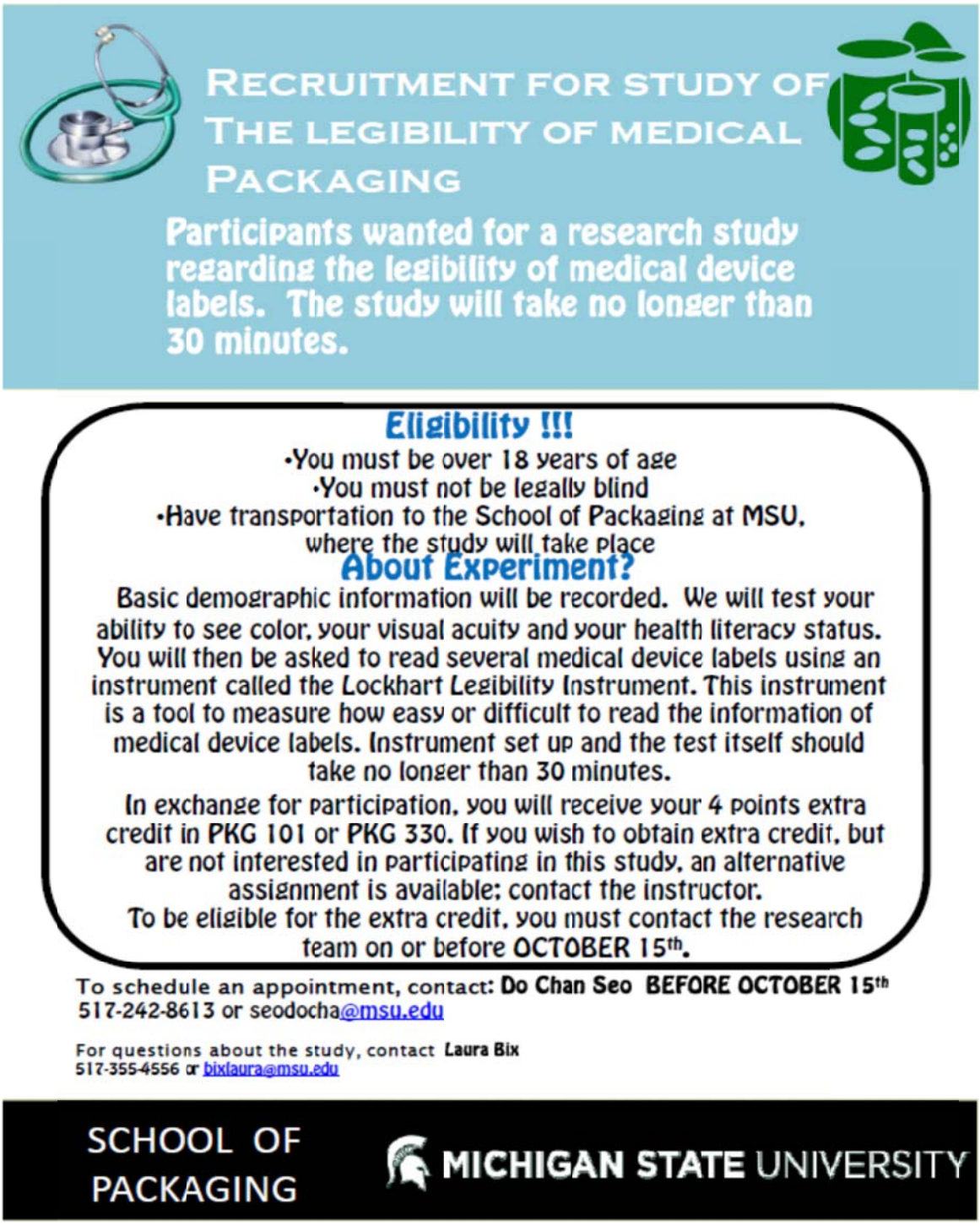


Figure 64. Recruitment flyer: Legibility test

APPENDIX 12. Recruitment flyer: Change Detection/Comprehension tests

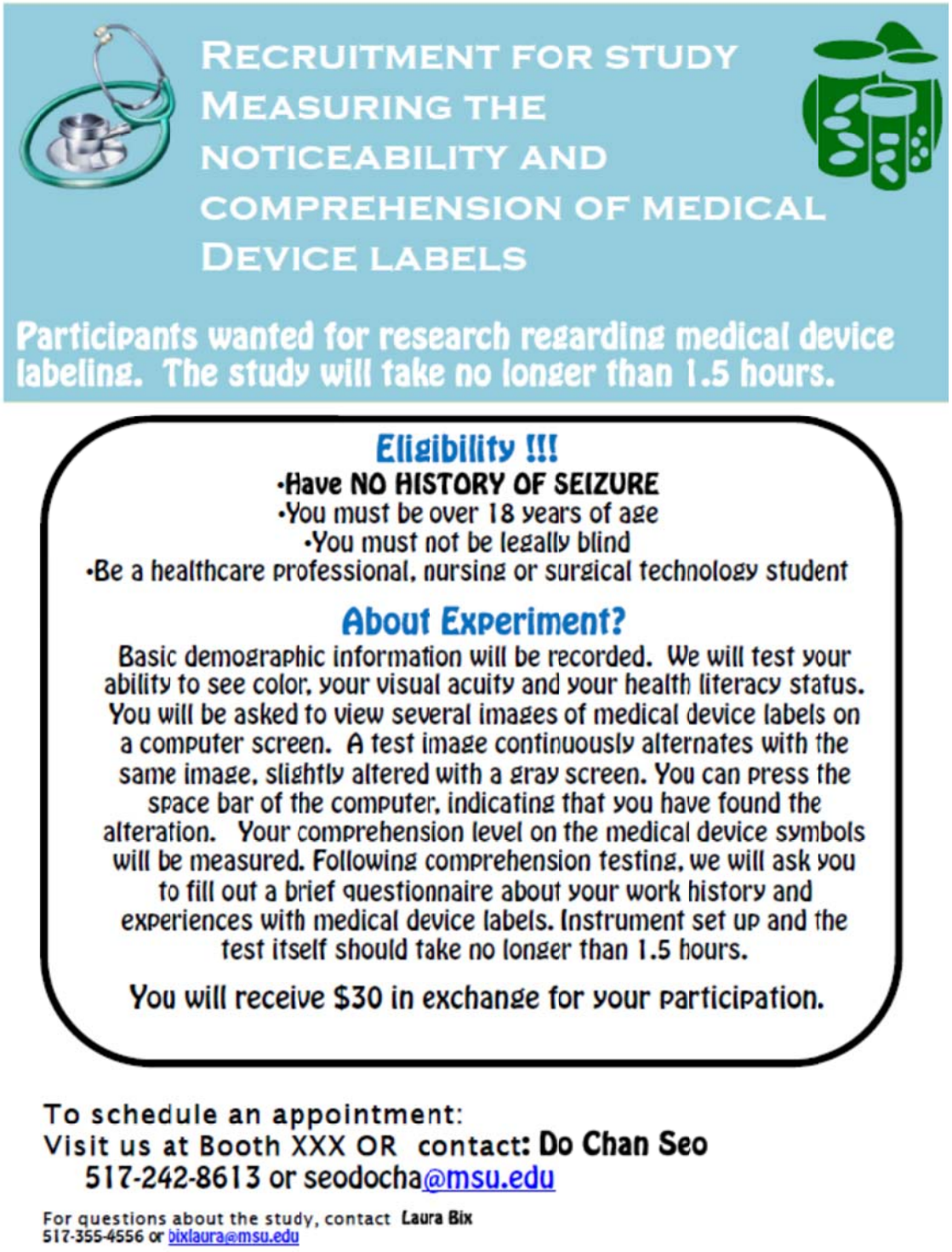


Figure 65. Recruitment flyer: Change Detection/Comprehension tests

APPENDIX 13. Recruitment flyer: Forced Choice Task test

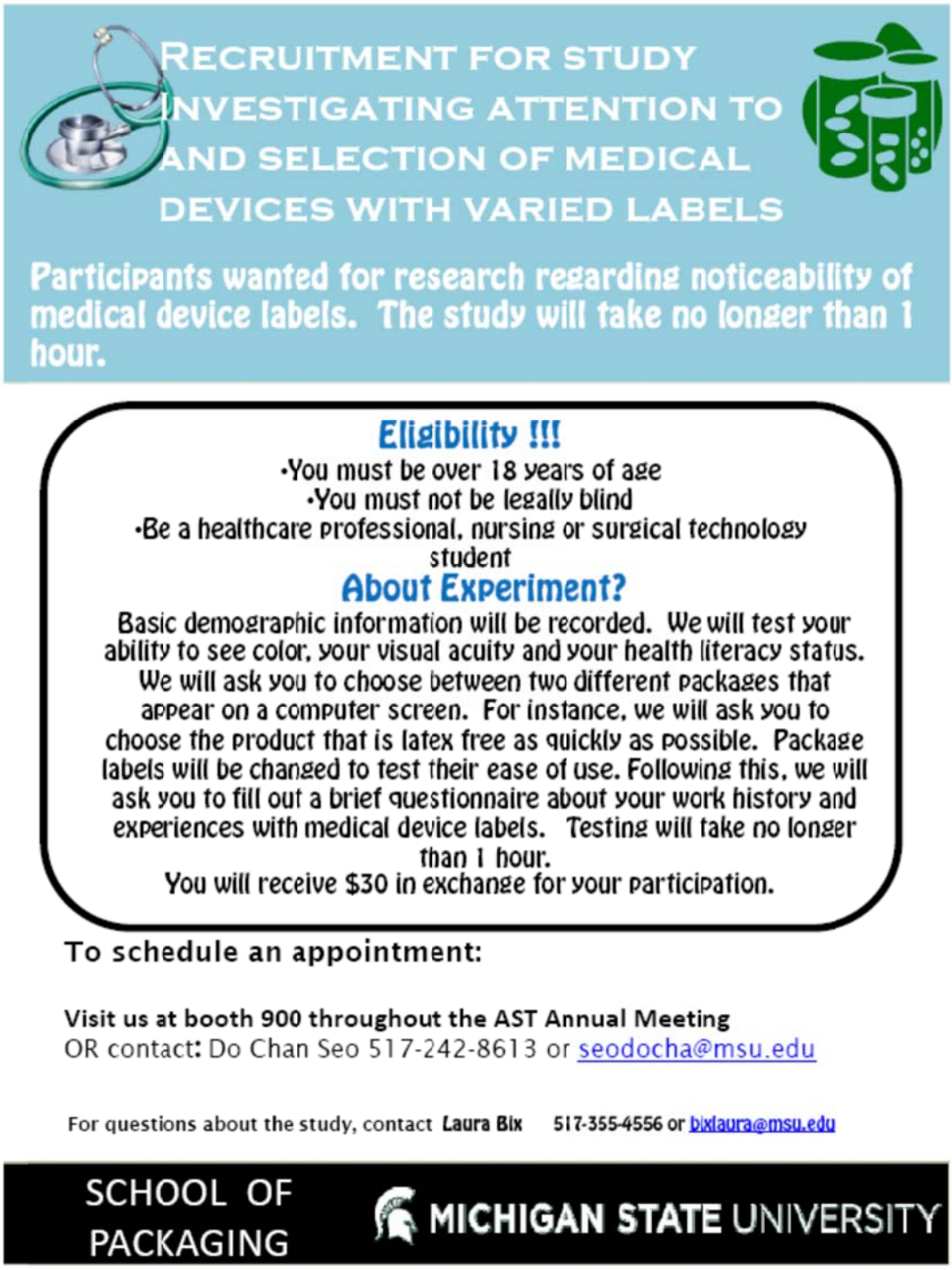


Figure 66. Recruitment flyer: Forced Choice Task test

APPENDIX 14. Critical pieces of labeling information (Change Detection)

Table 41. Critical pieces of labeling information (Change Detection)							
	Expiration dating	Sterility status	Latex status	Product Name	Use Instruction	Brand Name	Serial #
1 (Most important)	31	19	11	13	1	0	1
2	27	15	19	6	9	2	2
3	14	16	18	14	7	2	1
4 (Least important)	7	12	11	11	7	6	4
Total Frequency of Participant Responses	79	62	59	44	24	10	8
Median of Ranking	2	2	2	3	3	4	3.5
Mode of Ranking	1	1	2	3	2	4	4
	Date of Manufacture	Do not resterilize	Name	Manufacturer Name	Do not use if package is opened or damaged	Batch Code	Other
1 (Most important)	0	0	3	0	0	0	2
2	1	0	0	0	0	0	1
3	3	1	1	3	1	1	0
4 (Least important)	4	5	2	0	1	0	3
Total Frequency of participant responses	8	6	6	3	2	1	6
Median of Ranking	3.5	4	2	3	3.5	3	3
Mode of Ranking	4	4	1	3	3,4	3	4

APPENDIX 15. Critical labeling problems (Change Detection)

Table 42. Critical labeling problems (Change Detection)					
	Small font size	No standard location for critical information	Labeling designs not standardized	No color coding	No color contrast
1 (Most important)	44	18	8	5	7
2	21	21	11	14	9
3	6	15	20	11	9
4 (Least important)	4	4	10	4	4
Total Frequency of Participant Responses	75	58	49	34	29
Median of Ranking	1	2	3	2	2
Mode of Ranking	1	2	3	2	2,3
	Hard to get expiration dating information easily	Hard to get latex status information easily	Hard to get sterile statue information easily	Hard to comprehend symbol meaning easily	Other
1 (Most important)	2	0	0	0	0
2	2	3	0	1	1
3	3	0	2	0	2
4 (Least important)	3	0	1	0	4
Total Frequency of participant responses	10	3	3	1	7
Median of Ranking	3	2	3	2	4
Mode of Ranking	3,4	2	3	2	4

APPENDIX 16. Critical pieces of labeling information (Forced Choice Task)

Table 43. Critical pieces of labeling information (Forced Choice Task)

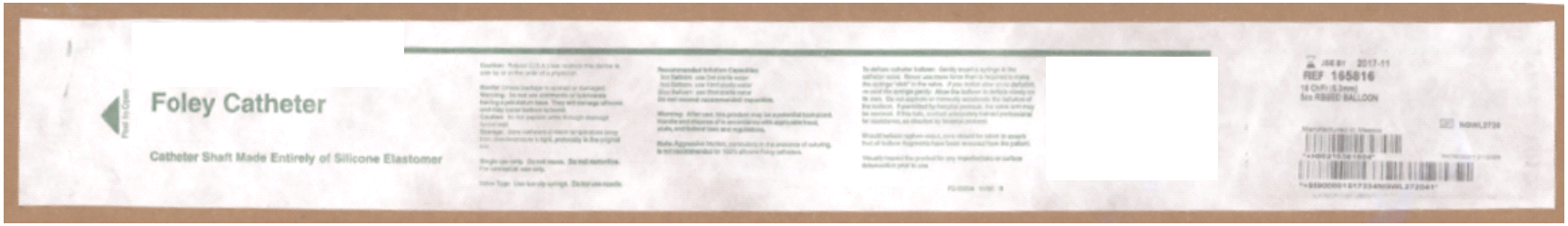
	Expiration dating	Sterile	Latex	Product Name	Use Instruction	Do not reuse	Name	Do not resterilize
1 (Most important)	22	20	10	18	4	1	4	0
2	25	20	17	9	7	2	0	0
3	20	15	15	10	7	1	1	3
4 (Least important)	11	4	17	5	8	5	4	5
Total Frequency of Participant Responses	78	59	59	42	26	9	9	8
Median of Ranking	2	2	3	2	3	4	3	4
Mode of Ranking	2	1,2	2,4	1	4	4	1,4	4
	Serial #	Brand Name	Date of Manufacture	Batch Code	Manufacturer Name	Do not use if package is opened or damaged	Other	
1 (Most important)	0	3	0	1	0	0	3	
2	0	0	0	0	0	0	6	
3	2	1	2	1	3	0	3	
4 (Least important)	5	2	4	3	2	4	3	
Total Frequency of participant responses	7	6	6	5	5	4	15	
Median of Ranking	4	2	4	4	3	4	2	
Mode of Ranking	4	1	4	4	3	4	2	

APPENDIX 17. Critical labeling problems (Forced Choice Task)

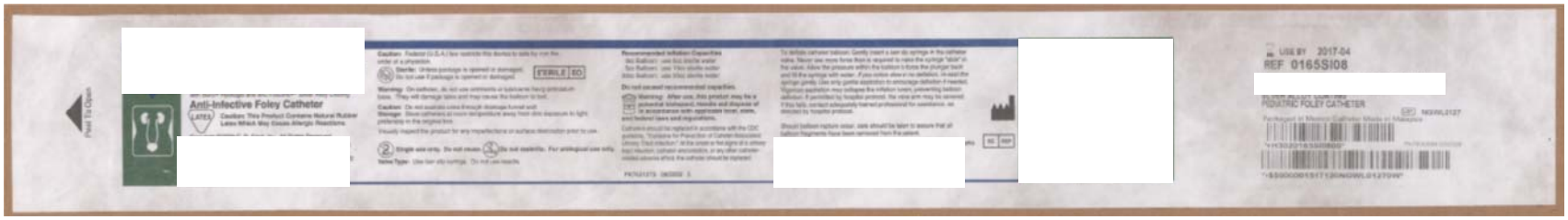
Table 44. Critical labeling problems (Forced Choice Task)					
	Small font size	No standard location for critical information	No color contrast	No color coding	Labeling designs not standardized
1 (Most important)	47	16	9	5	1
2	20	14	17	15	6
3	10	19	12	9	6
4 (Least important)	3	5	3	4	5
Total Frequency of Participant Responses	80	54	41	33	18
Median of Ranking	1	2	2	2	3
Mode of Ranking	1	3	2	2	2,3
	Hard to get expiration dating information easily	Hard to get latex status information easily	Hard to comprehend symbol meaning easily	Hard to get sterile statue information easily	Other
1 (Most important)	1	1	0	0	8
2	6	0	1	0	4
3	4	0	2	0	6
4 (Least important)	3	3	0	2	8
Total Frequency of participant responses	14	4	3	2	26
Median of Ranking	3	4	3	4	3
Mode of Ranking	2	4	3	4	1,4

APPENDIX 18. Benchmarking study labels

Sample 1



Sample 2



Sample 3

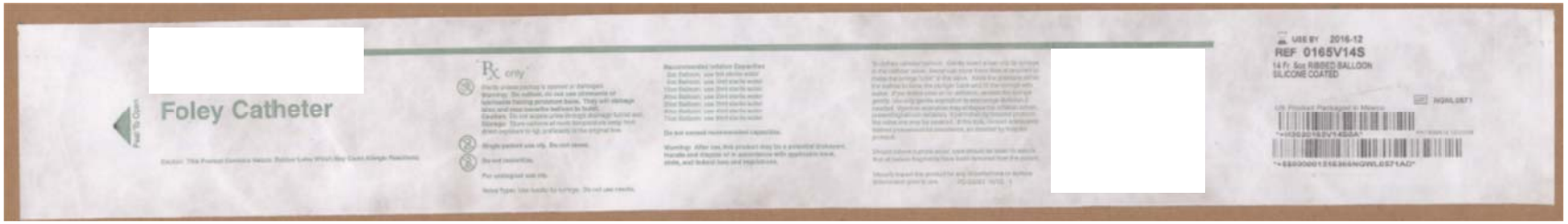
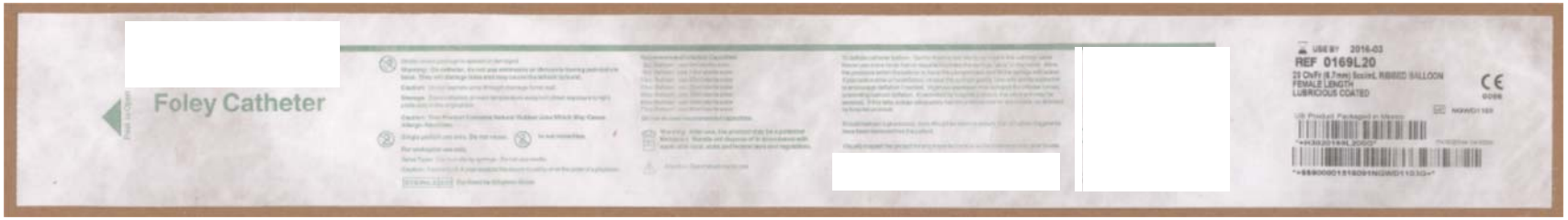


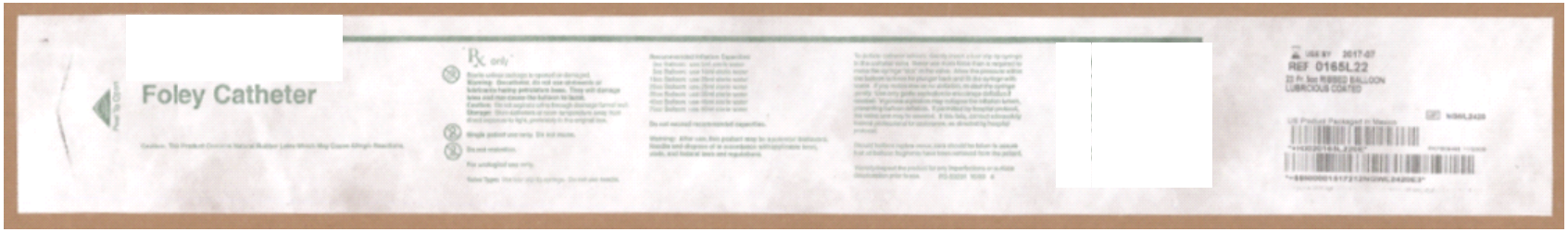
Figure 67. Benchmarking study labels

Figure 67. (Cont'd)

Sample 4



Sample 5



Sample 6

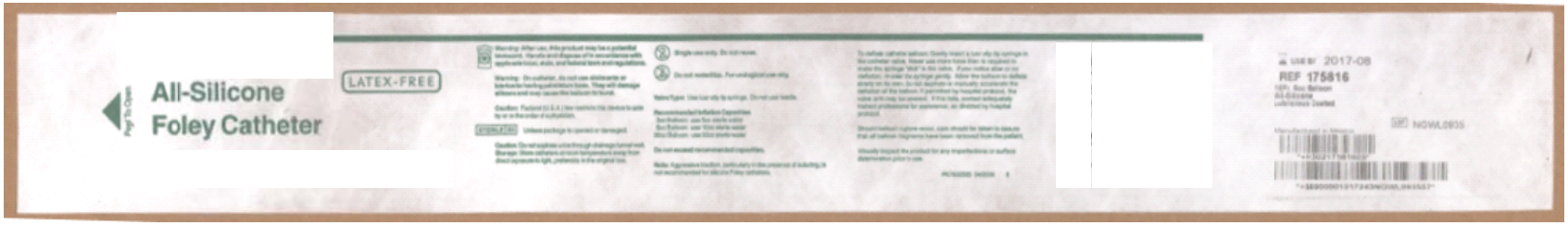


Figure 67. (Cont'd)

Sample 7

Sample 8

Sample 9

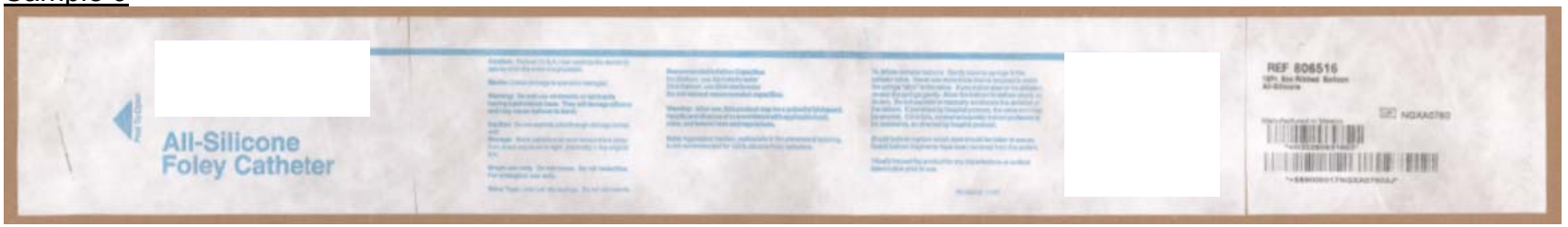


Figure 67. (Cont'd)

Sample 10

Sample 11

Sample 12

Figure 67. (Cont'd)

Sample 13

Sample 14

Sample 15

Figure 67. (Cont'd)

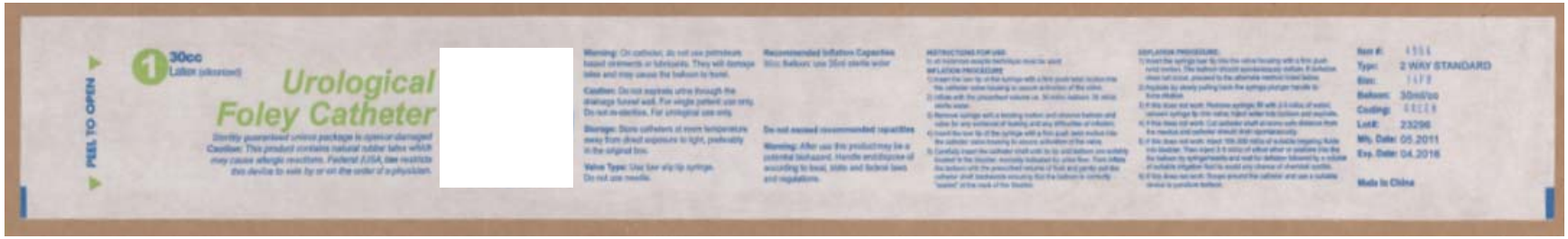
Sample 16

Sample 17

Sample 18

Figure 67. (Cont'd)

Sample 19



Sample 20

APPENDIX 19. Placement of critical information

Table 45. Placement of critical information

No.	Product name	Sub-product name	Latex	Sterile	Expiration dating
1	Location 1	Location 4	NA*	Location 2	Location 4
2	Location 1	Location 4	Location 1	Location 2	Location 4
3	Location 1	Location 4	Location 1	Location 2	Location 4
4	Location 1	Location 4	Location 2	Location 2	Location 4
5	Location 1	Location 4	Location 1	Location 2	Location 4
6	Location 1	Location 4	Location 1	Location 2	Location 4
7	Location 1	Location 4	Location 1	Location 2	Location 4
8	Location 1	Location 4	Location 1	Location 2	Location 4
9	Location 1	Location 4	NA*	Location 2	NA*
10	Location 4	Location 4	Location 4	Location 1**	Location 4
11	Location 4	Location 4	Location 4	Location 1**	Location 4
12	Location 4	Location 4	Location 4	Location 1**	Location 4
13	Location 4	Location 4	Location 4	Location 1**	Location 4
14	Location 4	Location 4	Location 4	Location 1**	Location 4
15	Location 4	Location 4	Location 4	Location 1**	Location 4
16	Location 1	Location 4	Location 1	Location 1	Location 4
17	Location 1	Location 4	Location 2	Location 2	Location 4
18	Location 1	Location 4	Location 3	Location 3	Location 4
19	Location 1	Location 4	Location 1	Location 1	Location 4
20	Location 1	Front side	Location 3	Location 3	Front side

***** Related information was not available.
** Different locations for texts and symbol: Texts were placed in location 1 and symbol, in location 4.

APPENDIX 20. Evaluation of text size of critical information

Unit: mm

Table 46. Text size of critical information

No.	Product name	Latex	Sterile	Expiration dating
1	5.162	NA*	1.260	2.248
2	2.182	1.222	1.264	2.234
3	5.134	1.268	1.242	2.202
4	5.032	1.196	1.272	2.222
5	5.182	1.324	1.176	2.170
6	5.130	Symbol only	1.308	2.606
7	5.114	1.174	1.196	2.168
8	5.212	1.420	1.272	2.170
9	5.162	NA*	1.266	NA*
10	2.278	1.474	1.642	2.770
11	2.326	1.870	1.602	2.628
12	2.148	1.572	1.58	2.744
13	2.394	1.516	1.546	2.872
14	2.334	Symbol only	1.642	2.218
15	1.370	Symbol only	1.608	2.022
16	3.628	1.420	1.506	2.180
17	4.362	2.000	Symbol only	1.644
18	5.490	2.010	1.740	2.262
19	6.072	1.650	1.656	1.736
20	3.098	1.136	Symbol only	1.142
Avg.	**3.941**	**1.483**	**1.432**	**2.223**
Max.	**6.072**	**2.010**	**1.740**	**2.872**
Min.	**1.370**	**1.136**	**1.176**	**1.142**

***** Related information was not available.

APPENDIX 21. Evaluation of text leading of critical information

Unit: mm

Table 47. Text leading of critical information				
No.	**Product name**	**Latex**	**Sterile**	**Expiration dating**
1	11.168	NA	NA	NA
2	NA	2.470	2.540	NA
3	11.170	NA	NA	NA
4	11.228	2.552	NA	NA
5	11.220	NA	NA	NA
6	11.306	NA	NA	NA
7	11.248	NA	NA	NA
8	NA	NA	NA	NA
9	7.898	NA	NA	NA
10	3.004	2.554	2.496	NA
11	3.968	2.618	2.454	NA
12	2.738	3.276	2.356	NA
13	3.228	2.49	2.392	NA
14	NA	NA	2.452	NA
15	2.858	NA	2.422	NA
16	5.958	NA	NA	NA
17	NA	NA	NA	NA
18	NA	3.330	2.914	NA
19	NA	3.638	NA	NA
20	5.704	2.018	NA	NA
Avg.	**7.335**	**2.772**	**2.503**	**NA**
Max.	**11.306**	**3.638**	**2.914**	**NA**
Min.	**2.738**	**2.018**	**2.356**	**NA**

NA: Leading for single line statement or symbol only was not available, or related information did exist.

APPENDIX 22. Evaluation of text color contrast of critical information

Table 48. Text color contrast of critical information

No.	Product name	Latex	Sterile	Expiration dating
1	Green/White	NA*	Green/White	Black/White
2	Black/White	Black/White	Black/White	Black/White
3	Green/White	Green/White	Green/White	Black/White
4	Green/White	Green/White	Green/White	Black/White
5	Green/White	Green/White	Green/White	Black/White
6	Green/White	Symbol only	Green/White	Black/White
7	Green/White	Green/White	Green/White	Black/White
8	Green/White	Green/White	Green/White	Black/White
9	Blue/White	NA*	Blue/White	NA*
10	Black/White	Black/White	Blue/White	Black/White
11	Black/White	Black/White	Blue/White	Black/White
12	Black/White	Black/White	Blue/White	Black/White
13	Black/White	Black/White	Blue/White	Black/White
14	Black/White	Symbol only*	Blue/White	Black/White
15	Black/White	Symbol only*	Blue/White	Black/White
16	Blue/White	Blue/White	Blue/White	Blue/White
17	White/Blue	Blue/White	Symbol only*	Blue/White
18	White/Blue	Blue/White	Blue/White	Black/White
19	Green/White	Blue/White	Blue/White	Blue/White
20	Blue/White	Blue/White	Symbol only*	Black/White

***** Related information was not available.

APPENDIX 23. Evaluation of symbol size of critical information

Unit: mm

Table 49. Symbol size of critical information

No.	Latex		Sterile		Expiration dating	
	Width	Height	Width	Height	Width	Height
1	NA	NA	NA	NA	3.274	**4.432**
2	**9.154**	8.280	**19.310**	4.456	3.344	**4.600**
3	NA	NA	NA	NA	3.282	**4.450**
4	NA	NA	**17.316**	3.622	3.328	**4.430**
5	NA	NA	NA	NA	3.252	**4.338**
6	Non-standard symbol		**14.630**	3.428	2.954	**2.954**
7	NA	NA	NA	NA	3.266	**4.478**
8	NA	NA	NA	NA	3.350	**4.374**
9	NA	NA	NA	NA	NA	NA
10	NA	NA	**17.656**	4.068	4.048	**4.592**
11	NA	NA	**17.634**	5.114	3.636	**5.668**
12	NA	NA	**16.618**	4.46	4.278	**5.850**
13	NA	NA	**16.916**	5.548	4.038	**5.506**
14	Non-standard symbol		**16.710**	4.244	2.110	**3.304**
15	Non-standard symbol		**14.860**	3.150	3.020	**4.496**
16	NA	NA	NA	NA	NA	NA
17	Non-standard symbol		**30.398**	6.58	5.038	**5.224**
18	NA	NA	**28.856**	6.77	Non-standard symbol	
19	NA	NA	NA	NA	NA	NA
20	**8.446**	7.158	**16.130**	4.534	3.036	**5.158**
Avg.	8.800	7.719	18.920	4.665	3.453	4.697
Max.	9.154	8.280	30.398	6.770	5.038	5.850
Min.	8.446	7.158	14.630	3.150	2.110	3.304

NA: Related symbol was not available.
A bolded dimension is a dimension of the square lines to contain each symbol.

APPENDIX 24. Evaluation of symbol color contrast of critical information

Table 50. Symbol color contrast of critical information			
No.	**Latex**	**Sterile**	**Expiration dating**
1	NA	NA	Black/White
2	Black/White	Black/White	Black/White
3	NA	NA	Black/White
4	NA	Green/White	Black/White
5	NA	NA	Black/White
6	Green/White	Green/White	Black/White
7	NA	NA	Black/White
8	NA	NA	Black/White
9	NA	NA	NA
10	NA	Black/White	Black/White
11	NA	Black/White	Black/White
12	NA	Black/White	Black/White
13	NA	Black/White	Black/White
14	Black/White	Black/White	Black/White
15	Black/White	Black/White	Black/White
16	NA	NA	NA
17	Blue/White	Blue/White	Blue/White
18	NA	Blue/White	Black/White
19	NA	NA	NA
20	Blue/White	Blue/White	Black/White

NA: Related symbol was not available

APPENDIX 25. Evaluation of originating symbol standard of critical information

Table 51. Originating symbols standard of critical information			
No.	**Latex**	**Sterile**	**Expiration dating**
1	NA	NA	ANSI/AAMI/ISO-15223-1
2	ANSI/AAMI/ISO-15223-1	ANSI/AAMI/ISO-15223-1	ANSI/AAMI/ISO-15223-1
3	NA	NA	ANSI/AAMI/ISO-15223-1
4	NA	ANSI/AAMI/ISO-15223-1	ANSI/AAMI/ISO-15223-1
5	NA	NA	ANSI/AAMI/ISO-15223-1
6	Non-standard	ANSI/AAMI/ISO-15223-1	ANSI/AAMI/ISO-15223-1
7	NA	NA	ANSI/AAMI/ISO-15223-1
8	NA	NA	ANSI/AAMI/ISO-15223-1
9	NA	NA	NA
10	NA	ANSI/AAMI/ISO-15223-1	ANSI/AAMI/ISO-15223-1
11	NA	ANSI/AAMI/ISO-15223-1	ANSI/AAMI/ISO-15223-1
12	NA	ANSI/AAMI/ISO-15223-1	ANSI/AAMI/ISO-15223-1
13	NA	ANSI/AAMI/ISO-15223-1	ANSI/AAMI/ISO-15223-1
14	Non-standard	ANSI/AAMI/ISO-15223-1	ANSI/AAMI/ISO-15223-1
15	Non-standard	ANSI/AAMI/ISO-15223-1	ANSI/AAMI/ISO-15223-1
16	NA	NA	NA
17	Non-standard	ANSI/AAMI/ISO-15223-1	ANSI/AAMI/ISO-15223-1
18	NA	ANSI/AAMI/ISO-15223-1	Non-standard
19	NA	NA	NA
20	ANSI/AAMI/ISO-15223-1	ANSI/AAMI/ISO-15223-1	ANSI/AAMI/ISO-15223-1

NA: Related symbol was not available.

APPENDIX 26. Evaluation of presence/absence of symbols for critical information

Table 52. Presence/absence of symbols for critical information

No.	Latex	Sterile	Expiration dating
1	No symbol/No text	Text only	Symbol/Text
2	Symbol/Text	Symbol/Text	Symbol/Text
3	Text only	Text only	Symbol/Text
4	Text only	Symbol/Text	Symbol/Text
5	Text only	Text only	Symbol/Text
6	Symbol only	Symbol/Text	Symbol/Text
7	Text only	Text only	Symbol/Text
8	Text only	Text only	Symbol/Text
9	No symbol/No text	Text only	No symbol/No text
10	Text only	Symbol/Text	Symbol/Text
11	Text only	Symbol/Text	Symbol/Text
12	Text only	Symbol/Text	Symbol/Text
13	Text only	Symbol/Text	Symbol/Text
14	Symbol only	Symbol/Text	Symbol/Text
15	Symbol only	Symbol/Text	Symbol/Text
16	Text only	Text only	Text only
17	Symbol/Text	Symbol only	Symbol/Text
18	Text only	Symbol/Text	Symbol/Text
19	Text only	Text only	Text only
20	Symbol/Text	Symbol only	Symbol/Text

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