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CUshop: A Simulated Shopping Environment Fostering Consumer-Centric Packaging Design & Testing

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CUSHOP: A SIMULATED SHOPPING ENVIRONMENT
FOSTERING CONSUMER-CENTRIC PACKAGING DESIGN &
TESTING

A Dissertation
Presented to
the Graduate School of
Clemson University

In Partial Fulfillment
of the Requirements for the Degree
Doctor of Philosophy
Computer Science

by
Charles Tonkin
August 2011

Accepted by:
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Abstract

Consumer product packaging provides product damage protection, extends product shelf life, and communicates product usage instructions to the consumer. Its collective contribution to the waste stream is notorious, but its role in product salability is much less understood. Consumers now make the majority of product purchase decisions while present at the shelf, and since they do it very quickly (within 5-8 seconds), and do not appear to adhere to strong brand loyalty as was once more common, packaging (and more specifically, its aesthetics and contrast with its competitors) plays a dominant role in the decision-making process. It is difficult, however, to measure and predict the effectiveness of package design via empirical consumer response testing, and even more challenging to seamlessly integrate consumer response measures into the package design process. The key to meaningful measurement of consumer behavior in the package design process is immersion of the consumer in a convincing environment that elicits natural shopping behavior. While an actual retail store offers the most realistic environment, controlling experimental conditions in this setting is problematic. An artificial simulation of such an environment is desirable for reasons of efficiency, cost, and flexibility. CUshop™, a unique laboratory mixing physical store elements with those akin to virtual reality simulation, is introduced. The laboratory has been created with the goal of priming participants into a *shopping context*, or shopping frame of mind, prompting realistic consumer behavior that can be measured and studied via objective forms of measurement (e.g., eye tracking).

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I would like to give special thanks to my advisory committee (Dr. Sam Ingram, Dr. Harold Grossman, and Dr. Tim Davis) as they showed an extreme amount of patience, provided support when I needed it, and were not shy about being straight with me when appropriate. This was particularly true of my advisory committee chair, Dr. Andrew Duchowski—he never gave up on me making it through this process, put up with my changing professional and educational roles, and probably most difficult for him, successfully dealt with my habit of extreme procrastination.

I also need to thank Shelby, Chase and Jenni for their support through this process. It took a lot of my time and focus away from them over several years, and whether they know it or not, it means everything to me to have them behind me.

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Thank you all,

Chip

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Chapter 1

Integrating Consumer Response Measurement into the Package Design Process

The role of packaging has progressed from merely protecting and preserving a product to the point at which it is largely responsible for attracting a potential consumer, differentiating the product from competitors, and communicating its purpose and use to the consumer. Because of its role in the distribution process, it has also grown to contribute significantly to the waste stream. Thus packaging design is a multidisciplinary art that combines structural and graphic design, understanding of performance and logistics requirements, consumer usability testing, and consideration of end-of-life disposal needs. While it may be easy to dismiss the importance of improving this process, because of the sheer size of the market and widespread use of products consumed (\$475 billion worldwide market [WPO 2008]), more efficient packaging can positively impact many aspects of society. Some obvious examples are minimizing food waste (27% of food is wasted [Kantor et al. 1997]), reducing landfill need (30% is from packaging [Cutler and Madden 2008]), curtailing theft in stores and within the supply chain (average inventory “shrinkage” of 2.5% of the revenue [Ennen 2000]), insuring product integrity and safety (\$200 billion lost internationally [Nill and Shultz 1996]), lowering the energy used in the distribution chain (11% of fossil fuel is used for the processing, packaging and distribution of food [Worldwatch Institute 2004]), and reducing the amount of product damage and customer returns due to inadequate packaging in the distribution chain (\$1.6 billion lost in the US alone [Klie 2003]).

Seemingly minor decisions made at many points during the packaging design process have substantial consequences later in the package’s life cycle, but for the most part, as is common practice in industry, the structural, performance, graphics,

marketing, sustainability and logistic design components occur as disjointed, serial steps with very little communication among them. Technology has now reached a point where most aspects of the design process can be integrated seamlessly into a single workflow allowing functional, structural, protective, and graphic elements to be developed and evaluated concurrently. Beyond effective use of technology, a holistic design workflow requires cooperation across a variety of disciplines that mandates mutual respect and a good balance between the scientific and creative/aesthetic members of the team (Figure 1.1 illustrates an example of this process). This type of cooperation is difficult to achieve in any particular organization, and it is especially challenging within academia because it requires bridging programs residing in different colleges with different views on research, industry outreach, and the curriculum.

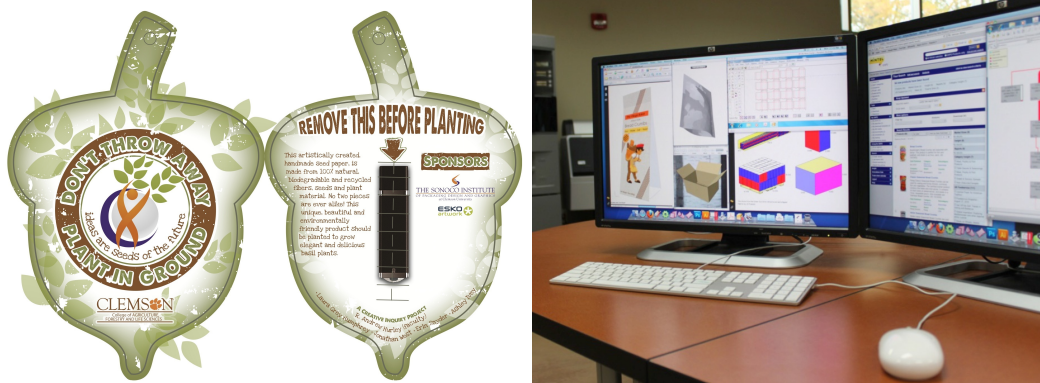


Figure 1.1: Holistic package design should include structural, logistics, performance, sustainability, graphics, consumer response and manufacturing considerations. As an example of this process, the package on the left was designed as a promotional item to hold a USB drive containing information about Clemson’s College of Agriculture. Aesthetically it is immediately obvious that this is a “green” product which is reinforced by the fact that the thumb drive is removed by punching it through the back like a seed. As a final cue, the paperboard substrate is made from seeds and fibers from basil plants, and the used package can simply be “planted” once the USB drive is removed.



Figure 1.2: Graphic Communications and Packaging Science students using state-of-the-art structural and graphic design software, running flexible film converting equipment, and measuring the spectral reflectance of printed ink films.

1.1 Sonoco Institute of Packaging Design & Graphics

Clemson University hosts two academic programs related to the packaging process, which have traditionally approached the teaching and implementation of packaging design from two very different perspectives with only some areas of overlap. Graphic Communications has focused on the graphic workflow from the creative concept through printing (with some limited converting as it relates to die cutting, folding, and binding) with considerable emphasis on the business and other practical realities of these applications. Packaging Science has approached the design process more from an engineering perspective that covers areas such as material selection, structural design, and performance evaluation. Students and curriculum content of both programs differ substantially as Graphic Communications emphasizes business content (management, marketing, and economics) while Packaging Science accentuates fundamental science (organic chemistry, biology, and physics). In both cases, however, the programs differentiate themselves from their competitors at other universities by offering hands-on laboratory classes that require students to acquire proficiency with a wide range of industry-standard equipment and procedures while working on real-world applications (see Figure 1.2). Because of their practical points of view and connection to industry, both programs contain a substantial percentage



Figure 1.3: The vision for the Sonoco Institute included design, prototyping, and production capabilities.

of students who transferred out of more purely academic fields (computer science, engineering, mathematics, etc.).

The applied approach taken by the departments was not accidental—industry partners such as Sealed Air/Cryovac, Printpack, and Sonoco were heavily involved in the creation and development of the curriculum and of the student-learning approach of both programs because there was (and continues to be) a strong need for graduates with these types of skillsets. The close relationship with industry partners continued as the programs developed and matured, and over time it was recognized that the potential opportunities between the two departments warranted a more formal program to tie them closer together. The desire for a program bridging academia and industry was initially driven by Sonoco and Harris Smith of Smith Container, and originally focused on developing a facility for both departments' students and faculty to work together on joint projects. Over time this initiative developed a wider focus and became more collaborative, garnering support and participation from various departments, Clemson University administration, and additional industry participants. This collaboration resulted in the construction of the Sonoco Institute of Packaging Design & Graphics (Figure 1.3).

Sam Ingram and Bob Kimmel (department chairs of the Graphic Communications and Packaging Science departments, respectively) developed the original vision

and business plan for the Institute. It was felt at the outset that a focus on packaging design and graphics combined with Clemson University's existing core competencies in advanced packaging materials, package safety, container manufacture, printing and transportation packaging, would provide opportunity to develop worldwide leadership in packaging and graphics innovation. The mission, as originally outlined, was to facilitate cross-disciplinary education, research, and public service in packaging design and graphics. This mission fits well with existing research and public service activities of both departments (which were primarily engaged with suppliers of machinery and materials, and with those companies that convert paper, plastic, metal and glass raw materials into packages and package components). Clemson is currently the only university worldwide to have brought together the related disciplines of packaging design/development and packaging graphics and printing. By taking creative license with the term "Packaging Design", however, the Institute's mission could be expanded further still to include other areas that add more value to the original proposition.

Packaging Design incorporates more than the structural and aesthetic elements that typically come to mind—done properly, the design process should incorporate a wide range of disciplines including material science, structural design, environmental sciences, manufacturing, marketing, and psychology. As this view became apparent, the mission broadened into something that has much greater impact and appeal across a broad range of industry participants and research areas. The Sonoco Institute intends to incorporate the knowledge and participation of industry partners to make significant contributions at three levels—as an academic stimulator, an industry resource for training and research, and a driving force to bring new technologies and innovations to the packaging and graphics markets. Students affiliated with the Institute have access to state-of-the-art equipment, have exposure to cutting edge technologies, and can gain invaluable experience through completion of industry-guided projects. Industry participants have access to a wealth of



Figure 1.4: The Sonoco Institute opened in March 2009—its vision was to include state-of-the-art capabilities for package design, prototyping, consumer evaluation, and pilot production. During its initial growth, several innovative projects have already come to fruition: an exceptionally strong, glue-less corrugated pallet design, several award-winning student projects combining food science products with innovative packaging tie-ins, and a handful of success stories with local entrepreneurs that led to the development of unique packaging solutions that enabled growth into large retail chains such as Lowe’s and Cracker Barrel.

unique capabilities along with fresh minds to help them tackle key technology and innovative packaging challenges (Figure 1.4). Along with tangible capabilities involving equipment and software, it was also necessary to develop a more holistic approach to the design workflow for use within the student curriculum and for driving industry design projects. During this process it became clear that in addition to including usability and end-of-life evaluation, economically driven sustainability metrics, and pilot level facilities for innovative functional printing integration, it made sense to add a component to address consumer behavior related to package design—intuitively it seems well understood that regardless of how well a package is functionally designed, if a consumer does not select and purchase the product, the design effort is wasted.

1.2 Relevance of Consumer Response

The manufacturing processes involved in producing a package are obviously very important, but what happens if the package does not convert into consumer hands? The shift in consumer buying behavior over the past two decades is forcing dramatic changes in the way products are designed, packaged, and marketed. Presently 70% of consumer purchase choices are made at the shelf, 85% are made without even picking up a competitive item, and 90% are made after looking at just the front face of the packaging [Clement 2007]. Even if customers are actively looking for a well-known brand, it is not enough to just present a nice looking package with clean graphics. Shoppers move quickly through categories and generally make a decision in 5-8 seconds, and if they do not see the product they are searching for, they select a substitute [Sorensen 2009]. This is well illustrated by the consequences of Tropicana's package redesign of their premium orange juice in 2009 (see Figure 1.5).



Figure 1.5: In 2009 Tropicana introduced a package redesign as part of a new advertising campaign (bottom row), but customers no longer recognized the brand and product, and sales dropped by 20% costing the company \$50 million [Young and Ciummo 2009].

Young and Ciummo [2009] pointed out that the removal of key graphic and logo elements, and the understatement of color-coding and flavor descriptors, significantly reduced the recognition and shopability of the product (sales dropped by 20% and cost the company \$50 million). The new look was created as part of a much larger advertising campaign, and in advertising, being bold and different can pay off, but as Sorensen [2009] and Underhill [2000] point out, the goals and reality are quite different in the retail world.

The retail environment is where a package “lives” until it is found and purchased by a consumer, and in order to understand the related requirements of a successful design, the following observations about retail are worth listing [Sorensen 2009]:

- 80% of shopper time is spent moving from place to place;
- an average grocery store has 30,000-50,000 SKUs and the average household only buys 300 different ones per year;
- the retailer’s profit comes largely from brand promotions rather than from margin on sales.

These observations speak to the hurry that the consumer is usually in, the variety of choices they have, and the fact that the retailer has very little incentive to optimize products and layout for the customer’s benefit. Underhill [2000] offers the following additional anecdotes:

- women tend not to buy items that require them to be in a position where their behinds can be brushed (coined the “butt brush effect”);
- the landing strip (place where customers enter the store) gets very little attention and is useless for most communication;
- basket size (or just the possession of a basket) has a much larger impact on the amount of product purchased than most other factors;

- time is critical—for many products, it takes a given amount of time to read and understand which is correct for the consumer and if it is too crowded or uncomfortable for this to happen, the consumer moves on (“irritated customers do not tarry...they leave”).

Another interesting impact of packaging on the consumer is its role in adjusting the perception of the product it contains. It is widely accepted that packaging sets the initial expectation of quality and value [Meyer and Lubliner 1998], but it has been shown to do more than that. Louis Cheskin coined the term “sensation transference” to describe the effect packaging aesthetics have on the perception of the enclosed product [Louw and Kimber 2005]. In taste testing it has been shown in many studies that various products (such as margarine and beer [Louw and Kimber 2005; Meyer and Lubliner 1998]) were perceived differently when served out of different packages. Gladwell [2005] made the observation that if the consumer thinks the product tastes better because of its packaging, then it does not really matter if there is really any physical difference in the product—the package and the product together create the overall impression.

Package design clearly plays a significant role in determining the success of a product, but as Clement [2007] points out, currently accepted design methodology often understates this impact and typically does not include objective methods of assessing the product’s visual impression on buying decisions. Some textbooks do mention tools such as the tachiscope (which measures the time at which it takes for a shopper to recognize a brand) and eye tracking (which measures visual priorities) [Meyer and Lubliner 1998], that perhaps can be used for this purpose. According to Young [2002], the most common way of evaluating new package designs and consumer appeal is through focus groups (qualitative investigation). Focus groups survey a small group of participants situated in an observed room (typically through one-way glass) during discussion and evaluation of a new product/package under the direction of an experienced moderator. While focus groups are relatively cost

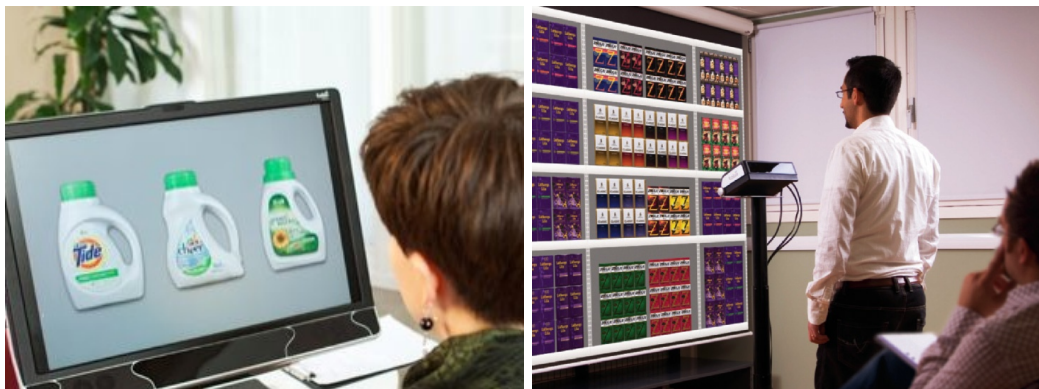


Figure 1.6: Commonly used eye tracking equipment in commercial packaging evaluation studies (Tobii T60XL monitor and Tobii X60 self-standing eye trackers).

effective and provide quick results, Young identifies a number of problems: they are comprised of a statistically small number of people; they tend to be dominated by strong personalities in the room; the moderator plays a very significant role; and the evaluation time-scale is generally longer than a realistic shopping experience (leading to “beauty contests”).

A number of leading industry representatives have addressed the issue of consumer behavior in a more regimented and objective fashion. In 2005, Dina Howell, the director of the First Moment of Truth (this particular phrase refers to the point at which the customer makes a purchase decision at the shelf) at Procter & Gamble was interviewed in a Wall Street Journal article. She related that P&G wanted to take in-store marketing, “from an art to a science”, and had developed a series of tests to quantifiably measure the success of its packaging and in-store marketing efforts. While companies like P&G do not divulge details of their methodologies, Howell said that their goal was for a packaging to “interrupt” a shopper. Basically each new package, with its design elements, must quickly answer: “Who am I? What am I? Why am I right for you?” [Nelson and Ellison 2005]. In a recent interview with three major industry figures (Christian Simms, associate director of consumer market knowledge at P&G, Pamela Waldron, Global Director at Johnson & Johnson, and Scott Young, president of Perception Research Services), the point was

made that these types of effects can not be measured by just observing and asking questions—a quantifiable method such as eye tracking or some other measurable means should be used to quantify the impact of packaging design on consumer behavior [George 2010] (Figure 1.6 shows common uses of eye tracking during package evaluation). Companies such as Kraft Foods, PepsiCo, and Unilever have also developed similar quantitative capabilities internally, and regularly employ eye tracking technology in the development of new packaging and retail strategies [Wedel and Pieters 2008]. Another example is Kimberly-Clark’s recently opened Customer Immersion and Design Center. The Center contains a life-sized virtual reality theater with 3D technology that lets retailers interact with new products and displays in their stores in an attempt at providing an experience similar to that of a real store. The digital nature of the products and display allows retailers to quickly try new ideas and scenarios at costs below experimentation in a real environment [McGee 2007].

The academic community has apparently fallen behind industry in the utilization of measured consumer response in the packaging design workflow. However, this type of measurement is not entirely novel as it is similar in many ways to prototyping evaluation in the Human-Computer Interaction design cycle [Preece et al. 1994]. The language used is slightly different, but the idea of generating a quasi-realistic prototype, obtaining experts’ and/or regular users’ contextual evaluation, and utilizing the resulting information in a formative way to iteratively improve the final product is analogous to the process that should be integrated into package design. In order for a consumer-based iterative process to be successful and to be adopted in the curriculum and innovative design, it needs to be more than a summative evaluation. The evaluation needs to be an integral part of the design process with some type of “shopability” or “noticeability” score (in place of the HCI’s usability) incorporated in a feedback loop in the creative part of the design workflow (as opposed to a research study or “disaster check” performed *post facto*).

The goal would be similar to performance simulation and other life-cycle study tools developed for the evaluation of package design (i.e., weight handling, sustainability, and shipping capability prediction tools), as it follows that one would also want to accurately predict a new package design's impact on consumer response prior to extensive development and manufacturing.

There are many approaches to the evaluation of packaging prototypes (in terms of consumer response). Eye tracking is one means of quantifying an observer's overt visual attention, and it can lead to comparison of visual search patterns of individuals in a variety of situations. Metrics include timed responses (e.g., 1st fixation, number of fixations, % area of interest, etc.), and survey results, among others. These approaches are readily applicable to the measurement of consumer behavior when searching for a product on a store shelf, and if placed in an environment that maintains ecological validity, the results should provide useful feedback improving the shopability of a package.

Chapter 2

Review of Consumer Response Measurement in Package Design

There are many ways of measuring consumer response. The most common method involves the use of focus groups, but one that shows a great deal of promise is eye tracking.

2.1 Eye Tracking in Packaging

Eye tracking has been shown to be a valuable tool in assessing consumer attention in shopping environments [Russo and LeClerc 1994; Wedel and Pieters 2008]. Recorded eye movements consist of two main types of motion: fixations, in which the eye is in a relatively stationary position and the fovea is focused on a particular area of scrutiny, and saccades, movements of a much higher speed that serve to shift the eye to the next fixation. Most of the eye's resolving power is concentrated within the 2° foveal region, and the focused view that fixations allow give us the ability to see fine detail in our environment (such as object identification on store shelves [Chandon et al. 2009]). It can be assumed that visual attention follows the fovea, although this is not always the case (one can covertly attend to an object in their periphery but must do so willfully; parafoveal visual attention is immeasurable and unlikely without effort in most unrehearsed tasks [Kramer and McCarley 2003]).

The parafoveal region surrounding the fovea provides an important function, however. While it has less resolving power and weaker color sensitivity than the fovea, it is responsible for peripheral vision and it provides a basic overview of the scene that may enhance search capability. When searching, the consumer can look in a parallel fashion thus perceiving visual impressions of the viewing environment



Figure 2.1: The three phases of the retail shopper’s search process—Orientation, Evaluation, and Verification as defined by Russo and LeClerc [1994].

(i.e., the store shelf) helping to orient and direct attention [Clement 2007]. Russo and LeClerc [1994] called this ability to evaluate overall patterns, colors, and shapes in the scene the “Orientation” stage (see Figure 2.1). Once an interesting object is spotted, the viewer transitions to a viewing mode (Russo and LeClerc called this the “Evaluation” stage) in which focus is on just one item and information is processed more intently and in a serial fashion [Clement 2007].

Chandon et al. [2009] compared selective vision to a person’s ability to hear and “feel” surrounding sounds or selectively listen in to a particular voice in a crowd (but not do both at the same time). This example highlights the fact that a task or particular selective action can be self-directed (top-down driven). This is in contrast to a bottom-up orienting reaction caused directly by a visual stimulus (i.e., a bright red package may attract initial attention regardless of intent). In practice there is a cooperation between top-down and bottom-up cognitive processing, and a great deal depends on the specific search task and initial conditions.

While consumers often enter a retail environment with some idea of what they intend to purchase (top-down driven), Lundberg [2004] pointed out that an increasing amount of decisions are made while at the shelf—80% are made at the point of sale with consumers spending less than 10 seconds in most grocery categories. In cases where there is clear brand recognition, both Underwood et al. [2001] and Orth and Malkewitz [2008] found that attention-getting packaging (imagery, colors, etc.) had less impact, but when brand was not a major consideration, this attention

was key in the buying decision. Chandon et al. [2007] showed that buying decisions are based on a combination of brand recognition and what they coined “visual equity”. This term refers to the incremental consideration given to items that attract a buyer’s attention so that while a consumer enters with a certain amount of “memory equity” related to their needs and understanding of brand value, this can be changed at the point of decision by what catches their attention. Eye tracking is a good tool for measuring this effect, and as Johansen and Hansen [2006] discovered during webpage navigation, individual recollections of what attracted attention and what order things were seen were not nearly as accurate as recorded eye movements. Additionally, because one may not remember what they saw or perhaps not even be truthful about the experience, the practice of measuring “brand recall” as typically done in marketing studies is largely meaningless. Chandon et al. [2007] showed “brand recall is overwhelmingly driven by brand familiarity” and, oddly, that eye fixations on products within a given market segment can enhance brand recall for the target product whether it is present in the study or not. They found that major brands tended to inhibit the recollection of minor brands while, conversely, the viewing of minor brands tended to enhance the recall of major brands.

The last phase of the process defined by Russo and LeClerc is the “Verification” stage. This is the point at which the consumer verifies that the product meets their needs, makes pricing comparisons, and garners assurance that it was the right product choice. In general, fixation number and length correlate positively to the winning product (particularly in the case of a major brand with significant memory equity) [Lundberg 2004]. Lundberg also recognized that when a consumer first “meets” a package, several factors impact the buying decision, and while there was a fair amount of overlap, she found that they can be grouped into three categories: Imagery, Impact, and Findability. Currently most of these attributes are studied using standard interview techniques, focus groups, and observation, but being able to objectively determine when, how long, and what attracts attention could give



Figure 2.2: To ensure ecological validity, it is critical for the subject to be in a “shopping context”, as depicted at left—the environment at right leaves much to be desired.

much more precise and actionable information than the softer, subjective responses typically garnered from a focus group [Young 2002].

Young [2005] makes the point that the most important factor in achieving applicable results is that the consumer must be kept in a *shopping context*. He stated that “when a shopper is removed from this context, she often leaves behind the shopping mindset and, instead, takes on an art director’s aesthetic mentality.” He compares this to a “beauty contest” in which the most aesthetically pleasing package tends to win (this is not typically the attribute that actually decides purchase decisions at the shelf). The lack of realism has been a significant problem in practically all of the consumer shelf studies thus far (compare contexts in Figure 2.2). Russo and LeClerc [1994] noted that the mean decision time in their experiment was well above industry norm (30 seconds vs. 12 seconds) and gave several likely experimental setup reasons for their subjects’ slower behavior. Clement [2007] reviewed this and other experiments and found that they presented serious validity problems because they were in laboratory experiments that poorly simulated real-world conditions. Subjects were sitting in chairs looking at pictures of packages or viewing relatively small projected images that were not accurate for size or visual angle. Even if subjects are shown an accurate picture with objects taking up the same amount of visual



Figure 2.3: Eye tracking in front of shelving at the Packaging Arena.

angle as a real life product, Tan et al. [2006] showed that performance on spatial tasks significantly improves as the image becomes larger.

Most consumer-related eye tracking studies have been restricted to environments in which the visual display was either projected on a screen or shown as a printed image. The Balance NAVE Automatic Virtual Environment consisted of three back-projected screens providing a wide field of view projection-based system [Whitney et al. 2006]. However, eye movements were not recorded, as their purpose was aimed at testing the effect of navigation through the environment on participants with and without vestibular dysfunction rather than testing shopping decisions.

In another study the number of shelf facings and position was evaluated by Chandon et al. [2009] with an eye tracker placed in front of *planograms* (a single 4'×5' screen, 80" away from the viewer).

The Packaging Media Lab, designed by The Packaging Arena, Ltd., and built within the Bergvik shopping centre in Karlstad, Sweden, was designed following Lundberg's [2004] recommendations, in which an eye tracker is used while a shopper views an image of a shelf of products on a screen. Wästlund et al. [2010] utilized this facility and describes its use and functionality in a recent study that evaluated perceived quality and shelf placement. Figure 2.3 shows this state-of-the-art laboratory in its current state, used as a consumer packaging evaluation facility in an



Figure 2.4: The Packaging Arena media lab utilizing rear projected images (note the space required behind the screen).

academic setting. The Lab contains a full size physical shelf for use with actual products and a well integrated virtual display that can mimic actual package sizes and proper consumer viewing distances. The display uses a rear projection system that avoids the shadowing issues and visual distraction that would occur in a front projected setup, and because of the geometry, it also maximizes the brightness and contrast of the images (see Figure 2.4). However, this setup does require a great deal of extra (and wasted) space behind the screen for it to provide a large enough image to use in packaging evaluation. While this design is effective, it prevents multiple screen systems to be used simultaneously and makes integration with physical shelving units difficult.

Previous package evaluation studies drew conclusions about consumer behavior based on their performance while viewing a display, but none of them compared differences in visual behavior between the projected screen and a physical shelf, or evaluated the difference between differently sized screens.

Important factors such as visual search patterns, behavior, and consumer performance could all be significantly impacted by differences in resolution, viewing angle, and contrast, as well as by the consumer's subjective impression of *presence* (or immersion within the environment). These facts were considered conceptually and some were measured empirically in the design of Clemson's consumer experi-

ence laboratory. To achieve ecological validity, it was necessary for the laboratory to possess the “look and feel” of a real shopping environment, the eye tracking equipment had to be unobtrusive and flexible, and the task needed to be structured and primed to instill the participant with a shopping mindset during the length of an experiment designed to evaluate package design.

Chapter 3

Design and Validation of Clemson's Consumer Experience Laboratory

The Sonoco Institute's vision of incorporating structural design, material selection, functionality, and printed communications to create innovative packaging is promising, but it misses a significant point that the consumer response ultimately determines the success of a product. However, it had not been clear how consumer focus could be integrated into a packaging design curriculum and related academic research programs. There were no other packaging programs that covered this area, and thus no referenced blueprint to work from. A useful early resource was Paco Underhill's book about consumers' behavior in retail environments—it provided a unique glimpse into the kinds of stimuli and environments that had non-random and consistent impact on behavior and purchasing patterns [Underhill 2000]. While it did not include eye tracking methodology, the book was the catalyst for realizing that much of a consumer's behavior in front of a store shelf is measurable and repeatable, and that perhaps this quantitative approach could be integrated into a packaging design workflow. Interest in consumer evaluation (and specifically eye tracking) led to preliminary collaboration with Clemson Computer Science students who became involved in evaluating aspects of packaging with various eye tracking strategies with currently available equipment and facilities. Although the results hinted at the potential value of this approach, these early studies illuminated several significant problems. It was evident that a much more specialized environment was needed than the Institute's auditorium available at the time. The auditorium used offered little control of lighting, allowed frequent subject distractions and interruptions, and the equipment and setup was not conducive toward gathering data consistent with a retail environment (in particular, projector throw and placement

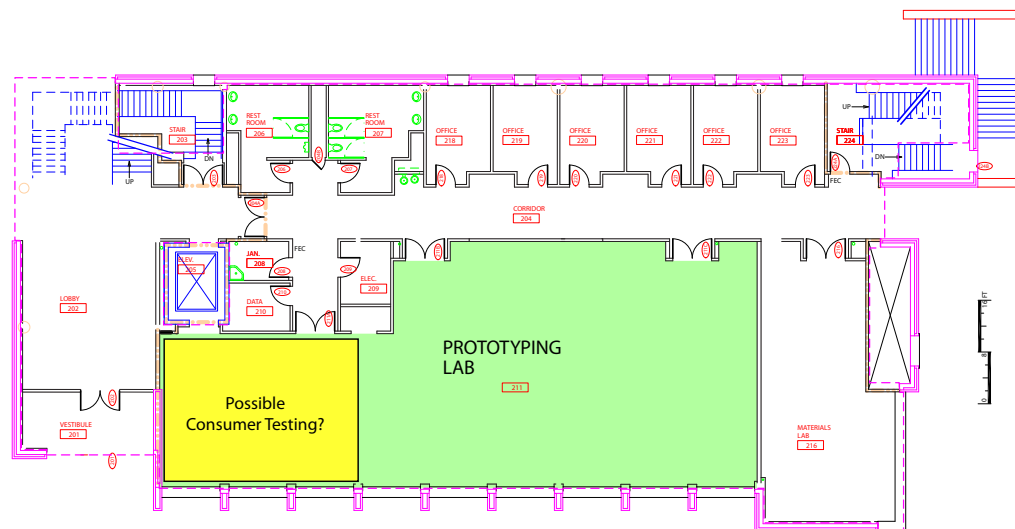


Figure 3.1: The original layout for the prototype lab on the 2nd floor—it did not include any facilities for consumer evaluation.

forced too far a viewing distance so that product size and level of detail could not be simulated adequately). The original plan for the Institute did not include space for a laboratory with capabilities to address these deficiencies, but it was felt that approximately 1,000 square feet of the prototyping lab could be dedicated to this purpose (see Figure 3.1).

In an effort to justify the design of a dedicated lab for consumer response evaluation, expert interviews were conducted with a variety of knowledgeable industry contacts as well as several Clemson University faculty involved in related research areas on campus. Dan Haney, of Haney PRC (personal communication on March 4, 2008) is co-owner of a business that primarily supplies Procter & Gamble with concepts and prototypes for new packaging [Thompson 2004]. Their layout and capabilities influenced the eventual Institute makeup. Although Mr. Haney had plans (and large amount of space set aside) for a consumer lab, a downturn in the economy apparently forced postponement of its construction.

Wilton Connor, previously of Wilton Connor Packaging (personal communication on November 14, 2008) felt that consumer behavior was critical to the design

process, and to his knowledge, this aspect was not taught anywhere as it related to package design. He had a unique consumer-focused point-of-purchase business model that called for building a retail area [Fortney-Rhinehardt 2001].

In describing research projects for Consumer Product Companies, Scott Young (president of Perception Research Services, a successful consumer research and testing firm, and author of many related academic and trade publication articles) spoke of the importance of displaying realistically-sized stimuli and stated that “to accurately measure shelf visibility, we’ve found that you really need to show product categories nearly life size. That’s why we project the categories at 6 feet wide, and it also corresponds to a shopper’s actual field of vision at the shelf. If you show a 6-foot-wide product category on a 20-inch computer monitor, the packages are too small to get an accurate reading of their shelf presence” [George 2010].

It was apparent from such interviews that it was not enough to simply use a monitor setup to evaluate packages individually (shown in the left image in Figure 1.6). The commercial approaches suggested by these industry partners and academic collaborators suggested the type of dedicated space and equipment needed for evaluating the consumer response portion of packaging design. Figure 3.2 shows the original concept and layout for the Consumer Experience Lab that attempted to provide a controlled environment to evaluate packaging products on shelves as well as a place for a large-scale virtual wall.

The challenge of creating a consumer experience lab was developing the workflow, equipment parameters, and environment to provide a realistic approximation of the retail shopping experience. In order for the space to be usable, it must suit a wide variety of products, remain cost effective, and lead to meaningful results. Typical eye tracking equipment and the bulk of published package evaluation research suggest the use of an all-in-one monitor system. This is sufficient for testing web usability and responses to printed ads and promotions because the size of the test stimuli readily fit the screens and the seating position of the subjects is natural.

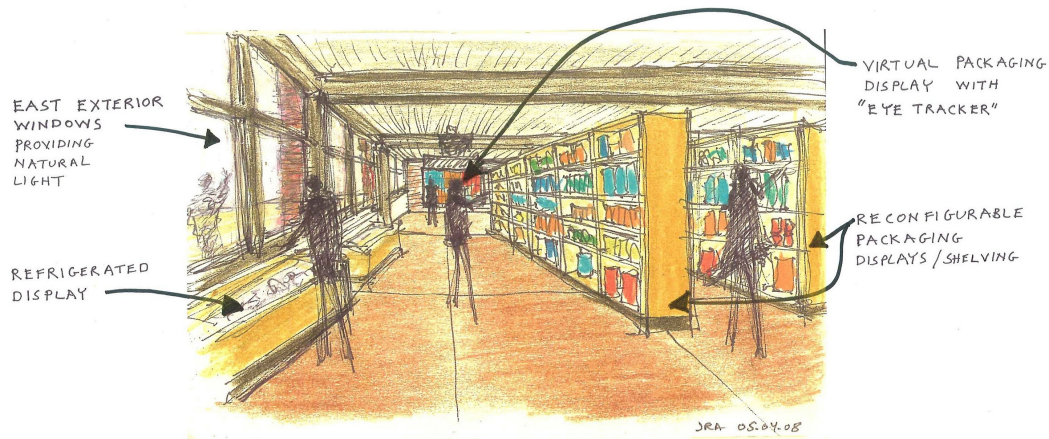
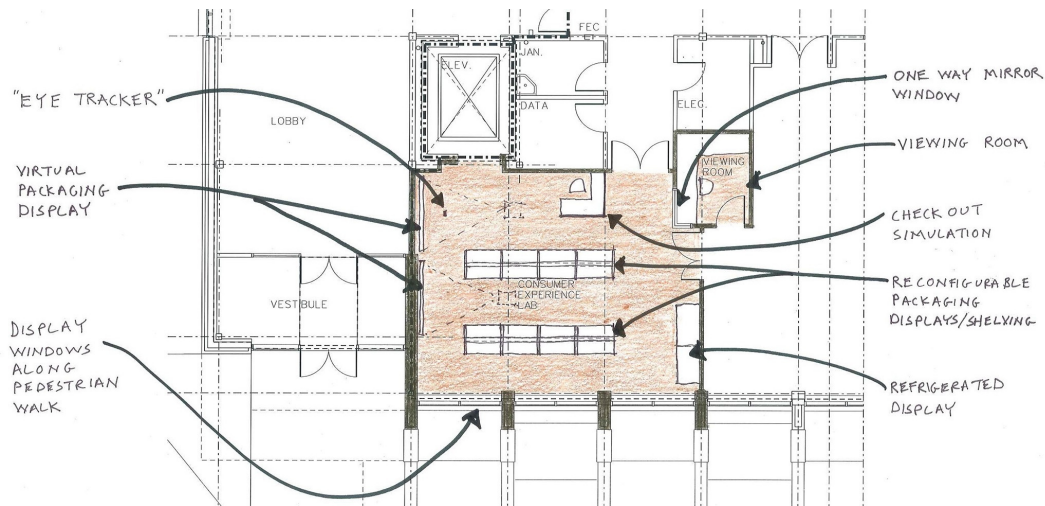


Figure 3.2: The initial concept for the Consumer Experience Lab (concepts by Josh Andrews - Lord, Aeck & Sargent, the Architectural firm that designed the original building).

However, this is not a realistic shopping simulation. Alternatives to the all-in-one embedded desktop system include self-standing eye tracking units that can be used in front of physical samples or a projector screens. These have been used for retail studies, but due to the awkward nature of the requirement of standing perfectly still in front of the shelf or projection screen, and the inherent limitation of just a single location, this arrangement is less than ideal for simulating the retail shopping experience. Nevertheless, the Consumer Experience Laboratory built as shown in



Figure 3.3: The functionality of the original lab was comparable to other research facilities, with a tripod-mounted eye tracker from Mirametrix (<http://www.mirametrix.com>).

Figures 3.2 and 3.3, was on par with current leading eye tracking labs engaging in consumer packaging studies within academia and commercial service providers [Lundberg 2004; Wästlund et al. 2010; Young 2010].

However, the commercial availability of an unobtrusive, wearable eye tracker led to a re-evaluation of how consumer response could be measured in actual environments and what conclusions could realistically be drawn from such measurements. Intuitively it made sense that to better simulate the shopping experience, consumers should be allowed to “wander up and down the aisles” as occurs in real shopping environments. The new wearable eye tracking glasses allow this freedom. It follows that the most realistic consumer experience study ought to be performed in an actual retail store with real products amongst real consumers. This is the direction many other researchers are following now that the equipment allows it, but there are problems. In some instances, performing the study on location makes sense as it is truly the “real” store environment and eliminates the need for simulation, but the logistics of regularly rearranging a store to meet experimental conditions, eliminating unwanted customer interaction, and controlling many other real-world variables make this prospect infeasible for many controlled studies under consideration. A hybrid environment, mixing physical elements of an actual retail outlet along with virtual simulation components was conceived.

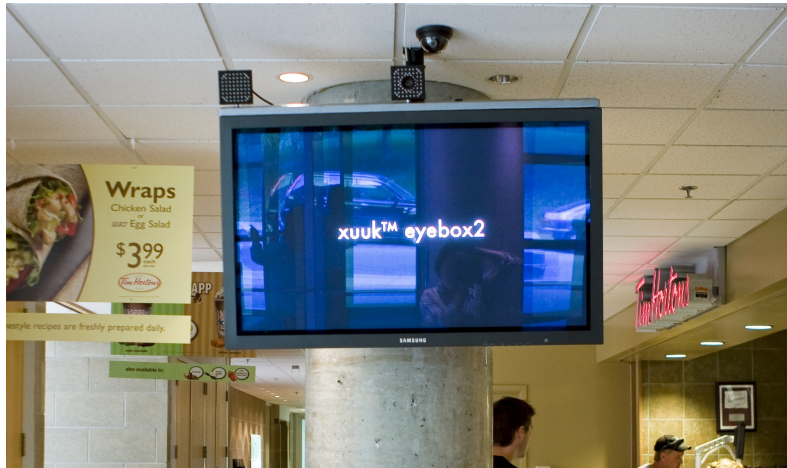


Figure 3.4: Xuuk’s *eyebox2* signage solution for capturing eye movements in a retail environment (from www.xuuk.com, with permission)

3.1 Consumer Experience Lab 2.0: CUshop™

Pervasive eye tracking systems seek to capture eye movements in large-scale, realistic environments [Shell et al. 2004], and an environment that is of particular interest to researchers of consumer behavior and package design is the shopping environment. Artificial (virtual) environments are designed to elicit consumer behavior that is hoped to be as realistic as what is experienced in a retail store. Capturing eye movements empirically in an actual shopping environment (e.g., with a mobile eye tracker) is infeasible due to the complexities of maintaining control of real-world variables for the conduct of scientific experiments (e.g., rearranging the store’s merchandise layout to meet experimental conditions). Until store shelves are embedded with eye trackers for capture of eye movements of passers-by (e.g., as is possible with limited accuracy with devices such as the *eyebox2*,¹ see Figure 3.4), gaze recording over store shelves is limited to construction of either simulated physical spaces filled with tactile objects, projection of simulated or real scenes on a flat canvas, or rendering of such scenes on computer displays (e.g., desktop or laptop).

The design for the consumer experience laboratory was achieved with the aid

¹www.xuuk.com



Figure 3.5: Rendering of the CUshop™ entrance.

of a team of 8 Graphic Communications, Packaging Science, and Architecture students that was supervised by Mr. Andrew Hurley (Lecturer in Clemson University's Packaging Science program) during the spring of 2011. Their task was to develop a retail environment layout along with the associated branding, signage and other accessories that would provide the best possible environment for future consumer response studies. They were given several constraints related to space, budget, specific required capabilities and timeline. The team delivered the design for the *CUshop™* consumer experience lab (a rendering of the entrance is shown in Figure 3.5) which simulates browsing freedom within a realistic environment.

The lab design called for a self-contained environment with sliding glass doors, re-configurable shelving, opening freezers, a refrigerated section, and appropriate signage and window treatments to create a realistic consumer shelf simulation. While it is understood that the physical environment is ideal, the lab was also designed

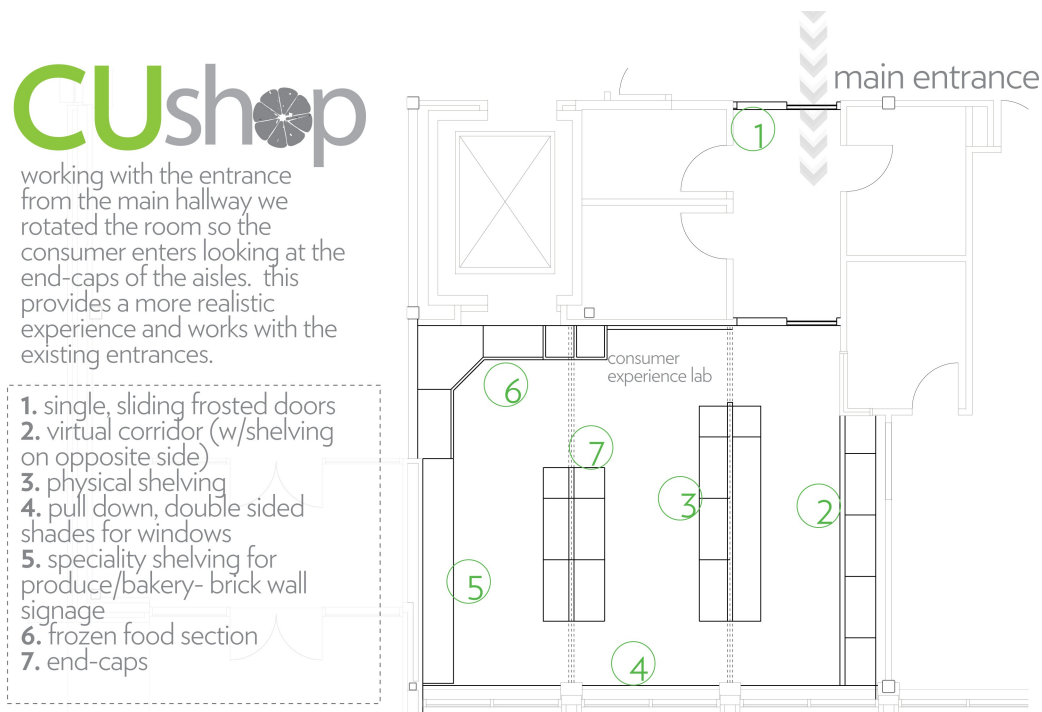


Figure 3.6: Layout of the CUshop™ to provide shopping area for package design evaluation.

to contain equipment to run studies within projected virtual environments because projection offers cheaper and faster setup while preserving a high level of stimulus control. A great deal of effort has gone into making projected virtual environments as real as possible with attention directed to size, positioning, and context of the surroundings. The use of projectors to simulate an otherwise expensive or difficult environment is not unusual. Flight and driving simulators have been used successfully for training and research purposes, and while they are not able to achieve complete physical or photo-realism, they have served as viable predictors of behavior in various situations [Tornros 1998]. Although patterns of information acquisition when viewing an image are expected to be similar to those when viewing the real environment, the general level of performance in object memory tests has shown to be better in the latter [Land and Tatler 2009].

3.2 Selecting Components for CUshop™ Development

CUshop™ was designed to include the necessary facilities to support consumer testing of a wide variety of packaging types, materials, and market segments. Its design required a mixture of functional elements to allow realistic and flexible display of products (configurable shelving, freezer units, refrigerated section and space for Point-of-Purchase display evaluation), good control of environmental conditions (temperature, lighting, shades for windows), and design cues that help the subjects enter the right frame of mind (“shopping context”—this includes cues such as signage and realistic logos, props like carts and baskets, sliding glass doors, appropriate building materials). In addition, the laboratory needs to accommodate control of testing parameters such as observation of the subjects, ease of calibration and use of eye tracking equipment, and the ability to process the proper number of subjects



Figure 3.7: Renderings for the future CUshop™.

without negatively impacting study efficiency. While it may not seem important, it is critical for the success of the overall Institute that the purpose and functionality of the lab also be easily communicated and demonstrated to potential customers and investors. Thus the end result should be easily mistaken for a small retail store, act as an effective research laboratory, and also serve as an exciting and innovative vehicle for stimulating interest in the support of the Institute. Figure 3.6 shows the layout and functionality and Figure 3.7 shows renderings of the CUshopTM consumer experience lab concept.

Another attribute that makes this laboratory such a good fit within the Institute is its potential to exploit the Institute's prototyping capabilities. In order to perform studies with actual packaging on shelves, large amounts of physical items are required, and while it is not only expensive and time consuming to acquire the necessary products at a local store, some of them may not be available in the local area or simply not yet exist. Thus being able to make use of state-of-the-art design and prototyping capabilities for creating realistic flexible and rigid plastic, paperboard, shrink sleeve, and corrugated packaging products is a key advantage enjoyed by the consumer lab.

While there was a desire to include some consumer evaluation of packaging design from very early in the construction phase, it was a low priority until an advisory board meeting in late 2010. At this point several key industry executives made a strong case for the potential benefits of immediately moving forward with this project. Participating Institute faculty and staff were convinced. More importantly, Harris Smith, who contributed over \$2.5M to the initial development and construction of the Institute, also advocated the project, devoting significant time to working with students and faculty in the design and integration of CUshopTM. He also provided the critical \$150K in funding for equipment, construction, and the graduate student stipend necessary to build the lab and establish the methodology in evaluating packaging. Over the course of four months, the team of students, charged



Figure 3.8: Tobii Glasses allowed eye tracking research in flexible environments.

with creating the layout and brand of the consumer lab, worked closely with industry partners to maintain the overall vision, University facilities staff to make sure building codes and other safety measures were met, and the proper research faculty to insure that the result would be a fully functional laboratory.

A catalyst for the lab concept was the introduction of the newly developed Tobii Glasses (shown in Figure 3.8). Previously commercially available eye tracking units that could be used in conjunction with actual shelves required the subject to be stationary during the testing phase. They also needed a time consuming calibration phase before beginning the study and the units themselves were very visible,

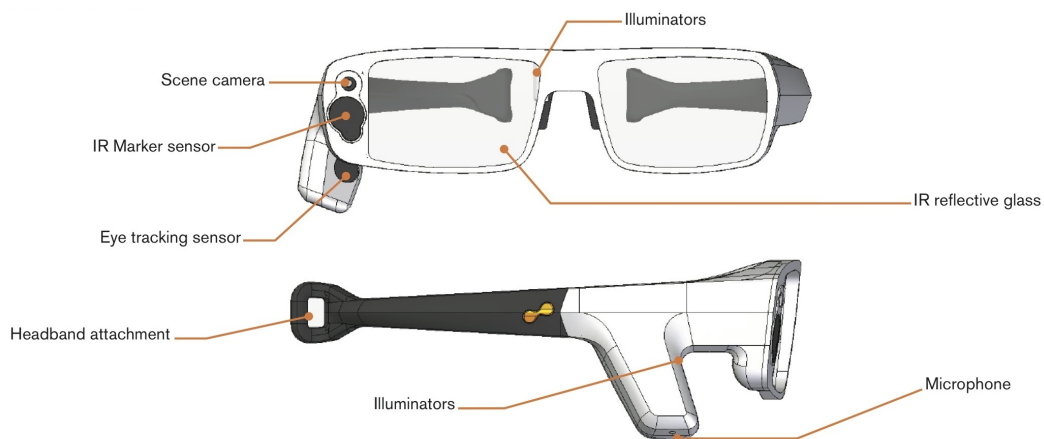


Figure 3.9: Tobii Glasses schematic—nothing obstructs the subject's field of view.

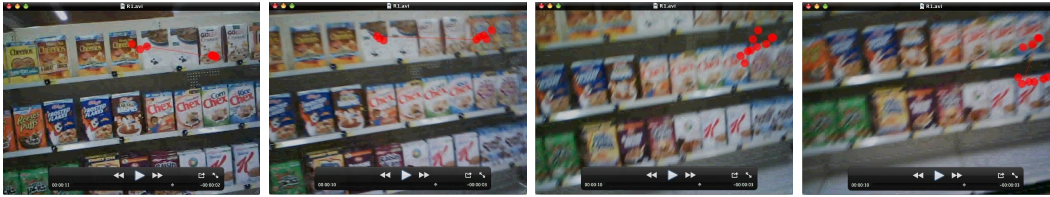


Figure 3.10: Frames from Tobii Glasses video footage.

generally interfering with the subject’s field of view. Calibration and visibility interference served as major sources of distraction for subjects, and at least to some degree, impacted results and the ability to study certain aspects of consumer behavior. One problem was the inability to view aisles as a consumer would see them initially—from the side as they walked down an aisle (a stand-alone system, for instance, required a stationary subject stand at a perpendicular point of view to line of shelves). The new Tobii Glasses, however, could be comfortably worn as the subject moved through the environment, and in contrast to other experimental wearable eye trackers, the Glasses’ eye tracking camera is not in the subject’s field of view and thus not a constant distraction (see Figure 3.9). The Glasses’ eye tracking camera is mounted to the side and slightly behind the right eye. Its placement allows recording of eye movements via reflection on the lens of the glasses, and because of its position, the camera is out of the subject’s sight. As with any wearable eye tracking system, another complication is the issue of mapping of the position of the recorded gaze points to physical environment. Tobii employs physical infra-red (IR) markers (shown in the right image of Figure 3.8)—four must be visible in every video frame recorded by the Tobii glasses to allow gaze point mapping.

After setting up the physical environment, the location of each marker is recorded by the Glasses. As the scene camera on the glasses records video of the subject’s view, it also records the IR markers’ locations in the scene. Recorded gaze points are subsequently processed by translating the recorded eye camera coordinate (in pixels on the individual frames of the video stream) to the scene camera coordinate by software (Tobii Studio). Figure 3.10 shows several (blurry and moving) frames from



Figure 3.11: Still image of shelf with IR markers that are used to map the physical space to the image space.

the Glasses' scene camera along with the local gaze point data. While it is interesting and sometimes valuable to view this moving data stream, it is not very useful for quantitative analysis because the data can not be easily aggregated from multiple subjects. The IR markers (visible in the frames) were recognized and mapped to the still image in Figure 3.11 making scan path comparisons, heat maps, and other visualizations possible.

Chapter 4

Empirical Validation of CUshop™ Design

Decisions

Two experiments were designed to evaluate the usability of monitors, projector screens, and physical shelving units during consumer experience testing. The first experiment attempted to determine whether there was a difference in subjects' responses to search tasks across a variety of products on different shelf sets displayed with larger, more realistically-sized images vs. a common size laptop monitor. The second study evaluated differences in consumer search performance and their perception of a physical vs. a virtual environment. Empirical results provided guidance in the eventual construction of CUshop™.

4.1 Study 1: Eye Tracking Over Small and Large Shopping Displays

Results of this study were presented as a note at the Pervasive Eye Tracking and Mobile Eye-Based Interaction (PETMEI) Workshop in Beijing, China, September 19, 2011, in conjunction with the ACM Conference on Ubiquitous Computing (UbiComp), September 17–21, 2011 [Tonkin et al. 2011].

The effect of display size on visual behavior was measured by performance (time and accuracy) and process (eye movements) measures. The main task was search for a target product, with display type as the primary experimental factor.



(a) lettuce



(b) lotion



(c) dressing



(d) freezer



(e) organic



(f) shampoo

Figure 4.1: The six product shelves, scaled to fit, from left to right: *lettuce*, *lotion*, *dressing*, *freezer*, *organic*, *shampoo*.



Figure 4.2: The six search target products, rescaled for clarity, from left to right: *lettuce, lotion, dressing, freezer, organic, shampoo.*

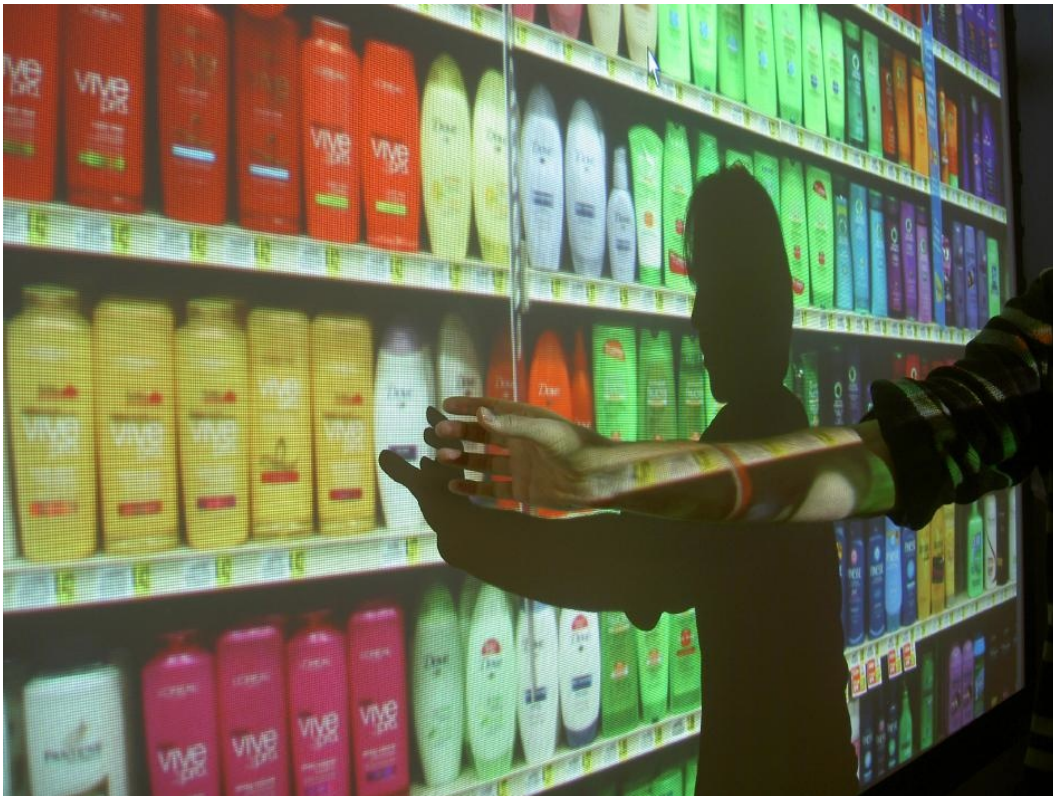


Figure 4.3: Testing apparent size of projected display.

Stimulus. Six images of product shelves were made in a local super market (see Figure 4.1), one for each type of search target, including *lettuce*, *lotion*, *dressing*, *freezer*, *organic*, and *shampoo*, as shown in Figure 4.2. To enhance the realism of the canvas display, the image was adjusted so that the apparent objects were realistically sized (see Figure 4.3). The same pictures were used on the laptop display (without any changes to size), so that participants saw different resolutions on the two displays.

Apparatus. The eye tracker used in this study was a prototype of the mobile Mirametrix S1 Eye-Tracker (Mirametrix Research Inc., Canada),¹ positioned in front of a 15.4" Fujitsu Siemens Laptop (Intel Core 2 Duo CPU, T5450 @ 1.66 GHz, 2.00 GB RAM) with display of resolution of 1280×800. Eye position data were sampled at 60 Hz, with a position accuracy of 1.0° visual angle [Hennessey and Duchowski 2010] within a limited range of head movement (25×11×30 cm).

The canvas was of size 117"×73" (11.5' diagonal) at a height 29" above the floor. The eye tracker stood at a distance of 126" from the screen on a tripod, which was elevated to a height of 54" above the floor and adjusted to fit individual participants' heights. The software application was written by Paul Schiffgens in C++ using Microsoft Visual Studio 2008 and Qt, an open source software development framework.

Experimental Design. The experiment consisted of a 2 (display) × 6 (product) mixed group factorial design, with display factored between-subjects and the product factored within-subjects (repeated measures).

Participants. We enlisted the help of 20 volunteers (9 female, 11 male, aged

¹www.mirametrix.com

Table 4.1: Mixed two-group factorial design used in the study.

	lettuce	lotion	dressing	freezer	organic	shampoo
canvas	G_1	G_1	G_1	G_2	G_2	G_2
laptop	G_2	G_2	G_2	G_1	G_1	G_1

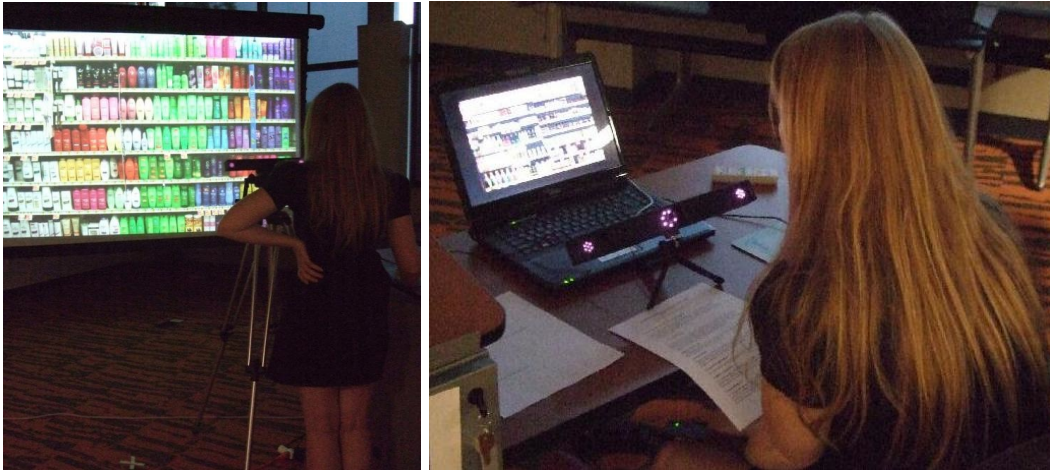


Figure 4.4: Participant at canvas and laptop displays.

between 15 and 36 years old), undergraduate or graduate students. Participants were split into two equal groups (each with equal number of males and females). One group searched for three of the products (lettuce, lotion, dressing) on one display (canvas) then the other three products (freezer, organic, shampoo) on the second display (laptop). The second group searched for the same products but with the display order switched. Order of search was counterbalanced (alternated between the two groups as given in Table 4.1).

Procedure. Before starting the experiment, participants were asked to stand in front of a canvas or sit in front of the laptop (see Figure 4.4). They then underwent a 9-point calibration process, with calibration dots appearing in the same left-to-right, top-to-bottom pattern either on the canvas or the laptop screen. The target item was then displayed until the participant indicated by clicking a mouse button that they had sufficiently examined it visually for the search to begin. The product shelf was then displayed next. Once the participant had visually located the target product, they indicated its location by moving the mouse on the target and clicking the mouse button once again (the same laptop was used for both laptop and canvas displays, a mouse was attached for clicking). The search process repeated for each of the six items located in each of the six product shelves.

4.1.1 Results

Of the 20 recruited participants, data collected from four had to be excluded from the analysis for various reasons related to calibration and IRB subject requirements. The remaining 16 participants consisted of 8 males and 8 females, aged between 18 and 36 years old (median 21).

Accuracy, measured in terms of location of the correct target product, varied across the six product shelves shown, with some of the products harder to find than others. Of the 16 participants, only 7 (44%) could find the lotion, 11 (69%) found the organic product, 12 (75%) found the dressing, 13 (81%) found the freezer item, 14 (88%) found the lettuce, and all 16 (100%) found the shampoo.

A two-way ANOVA of time to find the product, with the display acting as between-subjects fixed factor and the product acting as the within-subjects fixed factor (and participants serving as the random factor [Baron and Li 2007]), revealed that the main effect of product was highly significant ($F(5,75) = 5.20, p < 0.01$). The effect of display was marginally significant ($F(1,79) = 3.08, p = 0.08$).

A two-way ANOVA of the number of fixations prior to finding the product, with the display acting as between-subjects fixed factor and the product acting as the within-subjects fixed factor revealed that the main effect of product was highly significant ($F(5,75) = 5.52, p < 0.01$). The effect of display was marginally significant ($F(1,79) = 3.60, p = 0.06$).

Figure 4.5 displays the results graphically, with mean time and fixations prior to finding the product shown in (a) and (c). Times and numbers of fixation broken out by product type (listed numerically) are given in (b) and (d).

Mean time and fixations prior to finding the product grouped by product type are shown in Figure 4.6 along with typical scanpaths for easy- and hard-to-find products.

The above results contain all trials in which the participant claimed to have found the product (including those in which it was not clear from the eye tracking data

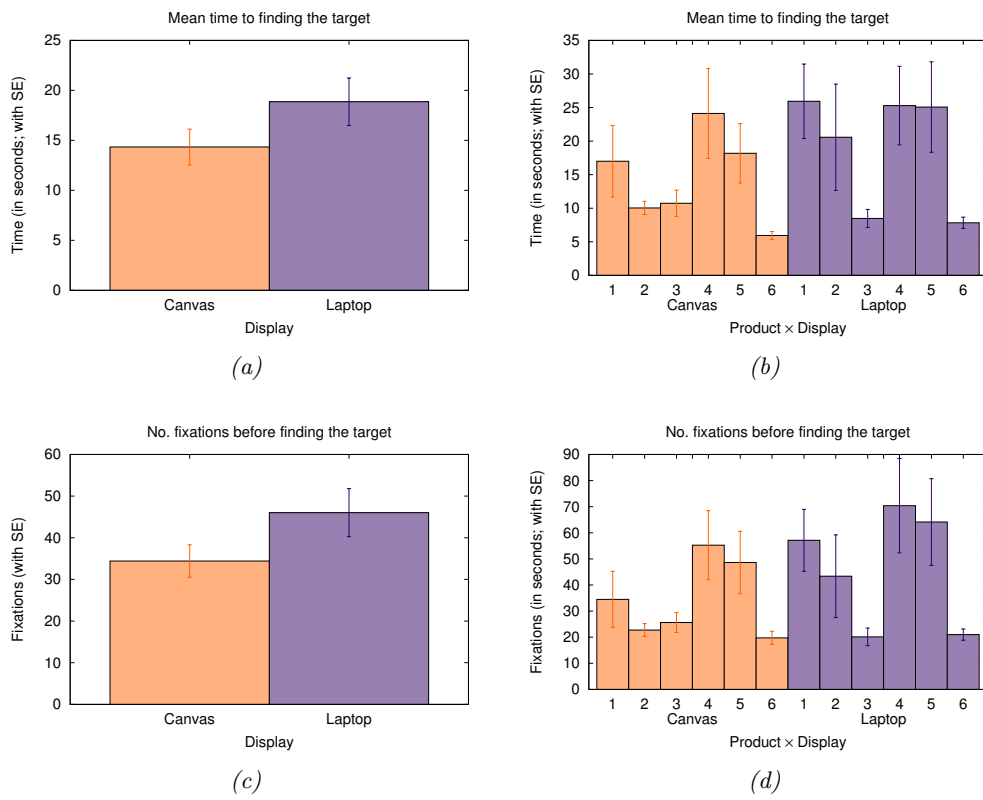
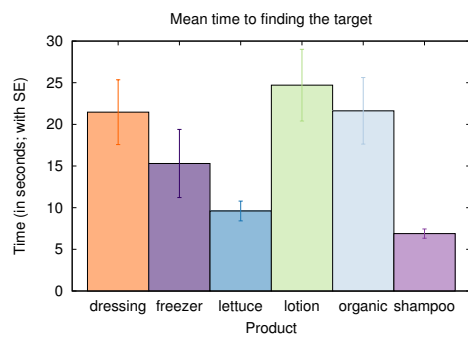
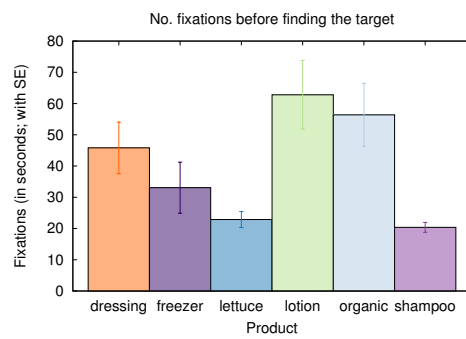


Figure 4.5: Results show that was the search task was marginally faster (and with less fixations) on the large canvas display



(a)



(b)



(c)



(d)

Figure 4.6: Results: performance and process metrics by product with typical scan-paths for easy- (shampoo) and hard-to-find (organic) items.

that they had in fact fixated upon the product before making the claim). Excluding trials not verified by fixation on target reveals a marginally significant main effect of product on both time ($F(5,52) = 2.19$, $p = 0.07$) and fixations ($F(5,52) = 2.29$, $p = 0.06$) with no significant effect of display on either time or fixations.

4.1.2 Discussion

Eye tracking data explains the discrepancy in search performance: because the number of fixations generally coincides with time taken to complete visual search, participants tended to search longer over the laptop display by casting more fixations. This difference in time to task completion may not have been evident had it been measured with a stopwatch because it would not been clear if they subject was actively engaged during the duration of the task.

The laptop display offers a smaller area for visual search, which would suggest less time required for complete coverage. However, it appears that the larger canvas display, on average, affords marginally better visual search performance, supporting earlier work indicating better performance on large displays [Tan et al. 2006]. The canvas subtended $50^\circ \times 32^\circ$ (visual angle) while the laptop's screen subtended $28^\circ \times 20^\circ$. One reason for the observed advantage in speed is that the larger field of view provided by the canvas offers better opportunity for the use of peripheral vision and hence better *preview benefit*—loss of contextual (preview) information is particularly problematic for tasks involving visual search [Greene and Rayner 2001].

Another reason for faster performance may be due to the participants' familiarity with the shopping task. Significantly faster search times were observed by Tonkin [2011] over physical shelves, suggesting that the more similar the task is to physical reality, the better the expected performance.

What is perhaps more striking about the present results is the significantly high variability in search times atop the six different product shelves. The highly significant effect of product on search time suggests that contextual information may

have more impact on search than the size of display. This observation, somewhat contrary to Russo and LeClerc's [1994] lack of difference in visual behavior over different product categories, suggests that visual search over real shelves may be highly dependent on how products are arranged, with factors such as shapes, colors, and layout each potentially heavily influencing visual search in physical (e.g., retail) environments. Results are more in line with Chandon et al.'s [2009] observation of effect of number and position of shelf facings on visual attention. However, further research is needed to validate this relationship.

While simulation environments such as CUshopTM could in the future contribute significantly towards the study of the arrangement of products and its impact on search, ultimately consumer behavior may best be studied by deployment of pervasive eye tracking systems embedded in store shelves.

4.1.3 Conclusion

Visual search was compared when searching for a product on simulated shelving on small and large projected displays. Larger displays tend to promote faster visual search times, although the composition of different shelf units (e.g., freezer, salad dressing, etc.) appears to carry even greater impact on performance. The significantly high variability in search times atop the product shelves tested exposes the importance of contextual information, which may influence search more than the size of display. Factors such as product shape, color, and shelf layout warrant further investigation.

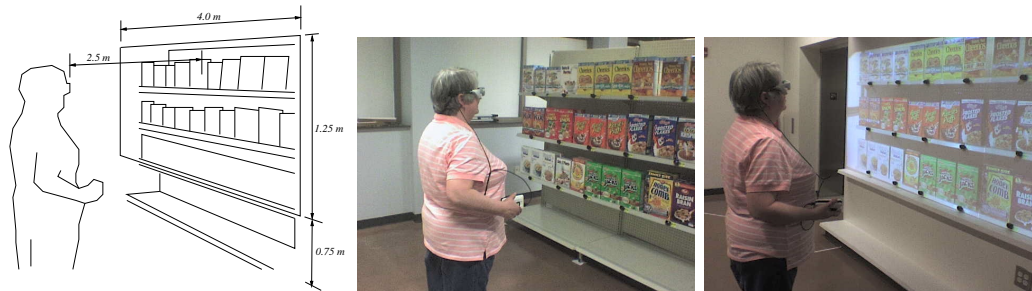


Figure 4.7: Physical and virtual viewing dimensions with example participant searching for target item.

4.2 Study 2: Eye Tracking Within the Packaging Design

Workflow: Interaction with Physical and Virtual Shelves

Results of this study were presented as a full paper at the Novel Gaze-Controlled Applications Conference in Karlskrona, Sweden, 26-27 May, 2011 [Tonkin et al. 2011].

The effect of physical or virtual environment was measured on performance (visual search), process (eye movements), and subjective measures (i.e., the feeling of *presence* within each environment and preference). The main task was search for a target item, with the main experimental factor consisting of environment type.

Stimulus. Two shelving environments were created for the experiment. The physical shelf was a 3.6 m (141") Aisle made with a Gondola 0.6 m (23") base system, constituting a 2 m (78") tall shelving system with four 0.4 m (16") deep upper shelves (this was used store shelving removed from a major US retailer). The shelf was populated with real physical cereal boxes with two fabricated cereal brands used as search targets.

The virtual environment was a snapshot of the physical shelf projected on a wall. The image was captured by a Canon EOS Rebel T1i 500D camera mounted

on a tripod approximating the eye-level of an average-height US adult (1.7 m (67")) [McDowell et al. 2008]). The image was then corrected for geometrical distortion caused by the lens, cropped, and resampled to achieve pixel dimensions of 2560×800 , and displayed across two Epson BrightLink 450 WI projectors, chosen for their brightness and short throw distance which eliminated shadow interference when standing in front of the display.

In both physical and virtual presentations of the cereal shelf, care was taken to present the participant with the same apparent view. In both instances the environment measured 4.0×1.25 m ($160'' \times 49''$) at an elevation of 0.75 m ($30''$) off the ground, as sketched in Figure 4.7. In both physical and virtual search tasks, participants stood centered at a distance of 2.5 m ($98''$) from either display.

The stimuli (see Figure 4.8) used as search targets were cereal boxes made especially for this study to preclude familiarity with the products. Artificial cereal boxes were created to ensure that they could not have been known *a priori* to any of the participants. Each box measured 22×28 cm ($8.5'' \times 11''$) and matched the dimensions of a box on the projector wall. Figure 4.9 shows one of the physical cereal boxes matching the dimensions of its projected counterpart.

Yellow and black price tags, visible in Figure 4.9, were also artificially created for this study and displayed below every distinct cereal box. Tobii's infra-red (IR) markers were placed atop the darker portions of the price tags in an effort to blend their appearance.

Apparatus. Eye movements were captured using Tobii Glasses, a head-mounted eye tracking system resembling a pair of glasses (see Figure 4.10(a)). The tracker is monocular (right eye only), sampling at 30 Hz with $56^\circ \times 40^\circ$ recording visual angle. The Tobii Glasses were used in conjunction with two other pieces of hardware: the Recording Assistant and IR markers. The Recording Assistant is a small device ($4.7'' \times 3.1'' \times 1.1''$) that attaches to the glasses and is used to both calibrate the eye tracker and store recorded eye movement and video data on a mini-SD card.



Figure 4.8: Artificial cereal boxes designed and constructed specifically for the experiment.

IR markers (see Figure 4.10(b)) are used to delineate an Area of Analysis (AOA), a plane determined by the placement of 4 or more IR markers, similar in concept to an Area/Region of Interest (A/ROI) commonly used in eye tracking research to delineate sections of stimulus within which filtered eye movements, i.e., fixations, are counted. The difference between an AOA and an AOI is that an AOA exists in physical space and is required for data aggregation when the glasses are used. An IR marker serves this function only when attached to an IR marker holder; otherwise, it works in calibration mode and emits a visible (green) light for calibration.

Calibration. Calibration using the Tobii Glasses is somewhat different from traditional calibration procedures employed with table-mounted, fixed, or more commonly known as “remote” eye trackers. To calibrate the glasses, an IR marker is used in calibration mode. The experimenter first asks the participant to stand at a distance of 1 m from a flat, vertical surface (e.g., a wall) and begins the calibration process using the Recording Assistant. The Recording Assistant then displays a



Figure 4.9: Physical cereal box held against its counterpart projected in the virtual environment.

3×3 grid of points to the experimenter, who must position the IR marker at each corresponding point on the wall. During this process, the participant is instructed to hold their head steady and follow the green light emitted by the IR marker with their eyes.

Experimental Design. The experiment consisted of a 2 (environment) × 2 (box type) × 2 (box placement) design. The environment was either the physical or virtual cereal shelf, the box type included two versions of a cereal box (Figure 4.8), and box placement featured the target box at one of two locations (left vs. right). A center target position was avoided as it is likely to be fixated first [Wooding 2002].

Each participant performed two trials, with environment and box type reversed in the second trial, counterbalancing trial combinations.

Participants. The study recruited 42 participants recruited from Packaging Science and Computer Science classes. Ten participants were excluded from analysis due to calibration issues (specifically we found that calibration points on the left

side of the grid were difficult for these participants to fixate; a possible consequence of the monocular nature of the Tobii Glasses). Four additional participants were excluded for incorrectly performing the task on at least one trial—data showed *post facto* that these participants never fixated the target box, their data could thus be considered off-target or erroneous. Analysis therefore considered only successful trials, consisting of data captured from 28 participants (18 male, 14 female). These participants' ages ranged from 20 to 42 (median 22).

Procedure. Before starting the experiment, participants were asked to fill out a basic demographic questionnaire (gender, age, use and type of corrective lenses, etc.). They were then walked to an unmarked, white wall for the calibration process. Participants stood 1 m (39") from the wall and underwent the 9-point calibration procedure. Ten participants could not achieve a satisfactory calibration and were thanked for their participation and dismissed.

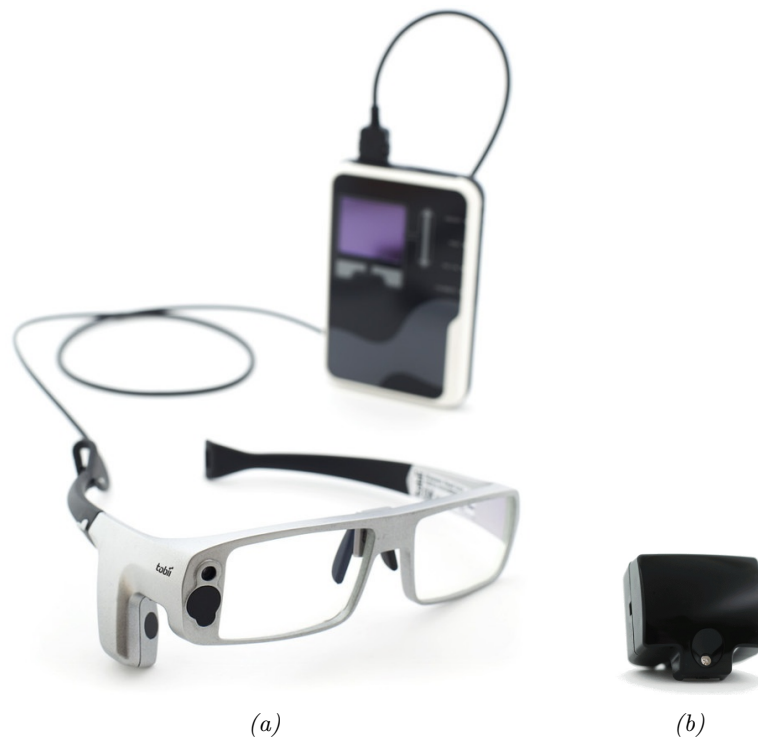


Figure 4.10: (a) Tobii Glasses, Recording Assistant, and (b) IR marker. Courtesy of Tobii Technology.

Next, participants were given instructions for their first task. If their task was the physical space task, the researcher showed the participant one of the two target boxes. The participant was told that their task would be to find this box on a physical shelf and verbally announce its price. They were given as much time as desired to examine their target box in as much detail as they wished (no participant spent more than 30 s). The participant was also shown examples of the price tags' appearance. They were then told the location of the physical shelf, and asked to walk directly to a marker on the ground (2.5 m (98")) from the stimulus) before looking up at the shelf. When ready, they were asked to look straight ahead so the glasses could auto-adjust for recording to begin. Finally, the experimenter walked with the participant to the shelf and recorded eye movements until the participant announced the price of the object. The physical shelving area was concealed from the participant prior to this task, to avoid preview benefit.

For the virtual space task, a similar procedure was followed, with the only difference being that the participant was walked to a marker 2.5 m (98") from a projector wall, and the image on the projector was changed from a blank image to the stimulus image when the participant was ready.

After the first task, the participant was given a custom-tailored Witmer-Singer [1998] presence questionnaire. The participant was given the option to remove the glasses while they took the questionnaire if they felt uncomfortable wearing them. Those who chose to remove them had to repeat the calibration procedure before the second task; however, only one participant elected to do so. Participants were then given their second task, with the same instructions. After completion of the second task, they were again given the presence questionnaire, but told that it referred only to their experience in the second task (be it physical or virtual). Finally, the participant was given a post-experiment questionnaire to collect subjective information (e.g., comfort) and any comments related to the study.

Search in the environments was counterbalanced such that half the participants

searched within the physical environment first and half first searched in the virtual. Position of the target box was also counterbalanced so that one quarter of the trials contained the target at left, another quarter at right and vice versa (corresponding images of the physical environment were used in the virtual projection).

4.2.1 Dependent Measures

Eye Tracking Metrics. The primary metric of interest was time to first fixation on the target box. This metric effectively measures time to task completion, or performance of the task. Additionally, we measured the number of fixations prior to the first fixation on target. We considered, but rejected, other eye tracking metrics such as fixation duration. In this type of visual search task, a participant’s eye movements typically consist mostly of saccades until the target is found. After the target is found, the number or duration of fixations on it give us no further information—we were mainly interested if the time to location of the target differed between environment types.

Presence Questionnaire. A presence questionnaire, based on Witmer and Singer’s version 3.0, tailored to the present experiment, was used to gauge participants’ subjective impressions of both environments, specifically along four subscales: immersion, involvement, sensory fidelity, and interface quality. Four questions were chosen from the immersion and involvement subscales and three from the sensory fidelity and interface quality subscales. All questions were administered along a 7-point Likert scale. Questions relating to non-visual senses were omitted.

4.2.2 Results

Eye movement data in the form of numbers of fixations and time to first fixation of the target AOI were exported from Tobii Studio for analysis with R [Baron and Li 2007].

A repeated-measures three-way ANOVA of time to first fixation revealed sig-

nificance of the main effect of environment ($F(1,27) = 22.77, p < 0.01$). No other significant effects (of box type or placement) were detected (see Figures 4.11(a) and 4.11(b)).

A repeated-measures three-way ANOVA of the number of fixations prior to the first fixation on the target also revealed significance of the main effect of environment ($F(1,27) = 16.56, p < 0.01$) but not of box type or placement (see Figures 4.11(c) and 4.11(d)). Both of these results suggest that search performance is faster in a physical environment than on a virtual projected image.

Results from the modified Witmer-Singer Presence Questionnaire were analyzed following Madathil and Greenstein’s analytical approach, by first computing the mean responses of questions related to each of the four subscales used and then comparing differences between each of these means (of means) via a Welch two-sample t-test between physical and virtual trials [Madathil and Greenstein 2011]. No significant differences were observed between the means of any of the four subscales tested (see Table 4.2 and Figure 4.14). A trend toward higher perceived fidelity appears to point toward the physical environment, but, on average, the effect is negligible. Furthermore, modal responses to the subjective post-experiment questionnaire show neutral preferential attitudes to either of the physical or virtual (projector) tasks (see Table 4.3).

4.2.3 Discussion

Results indicate that the physical environment afforded significantly faster search performance than the virtual projected image. The eye tracking data provides clear evidence of the discrepancy in performance: because the number of fixations generally coincides with time taken to complete visual search, it is clear that participants took longer in the virtual environment because they had to issue a larger number of fixations. This is visualized in Figure 4.13 and shows the reason for the difference in time to task completion. The difference might not have been evident had this

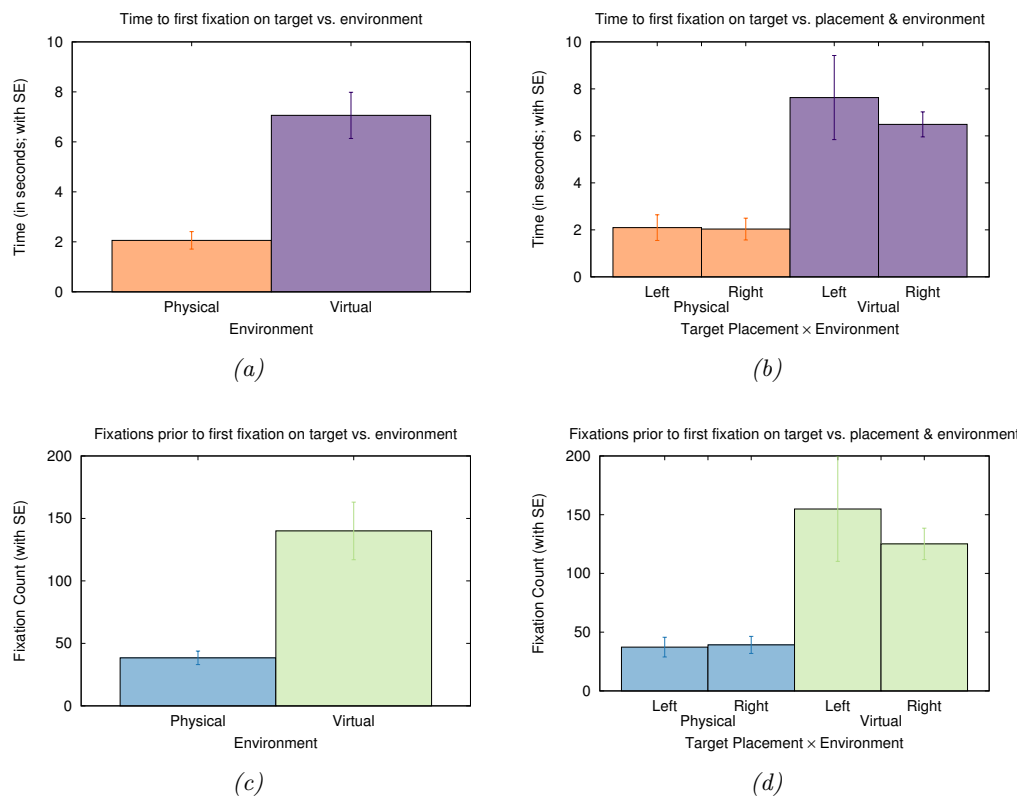


Figure 4.11: Results indicate that the physical environment afforded significantly faster search performance than the virtual projected image.

Table 4.2: Mean responses to the tailored Witmer-Singer presence questionnaire, marked on a 7-point Likert scale with 1 indicating most negative agreement and 7 indicating most positive agreement to the given question regarding experiences in either virtual or physical environment.

#	Question	Physical env.	Virtual env.
<i>Involvement</i>			
1.	My interactions with the shelving environment seemed natural.	6.1	4.6
3.	The visual aspects of the environment involved me.	5.8	5.1
8.	I was able to completely survey or search the environment using vision.	6.4	6.2
11.	I felt involved in the search task.	6.0	5.8
	<i>group means (means of means)</i>	$\overline{6.1}$	$\overline{5.4}$
<i>Immersion</i>			
2.	All my senses were completely engaged.	4.6	3.8
4.	I was completely aware of events occurring in the real world around me.	5.9	5.1
6.	The information coming from my visual sense felt inconsistent or disconnected.	2.5	3.2
12.	I was distracted by display devices.	2.9	3.2
	<i>group means (means of means)</i>	$\overline{4.0}$	$\overline{3.8}$
<i>Sensory Fidelity</i>			
7.	My experiences with the shelving system seemed consistent with my real-world experience.	5.9	4.6
9.	I felt that I was able to examine objects closely.	5.4	4.9
10.	I felt that I was able to examine objects from multiple viewpoints.	4.5	3.9
	<i>group means (means of means)</i>	$\overline{5.3}$	$\overline{4.5}$
<i>Interface Quality</i>			
5.	I was completely aware of any display and control devices.	5.9	5.1
13.	Visual display quality interfered or distracted me from completing my task.	2.2	3.0
14.	I was able to concentrate on the search task and not on the devices used to perform the task.	6.1	5.2
	<i>group means (means of means)</i>	$\overline{4.5}$	$\overline{4.6}$



(a) Physical environment



(b) Virtual environment

Figure 4.12: Heatmaps (all participants) in either environment.



(a) Physical environment



(b) Virtual environment

Figure 4.13: Scanpaths (all participants) in either environment.

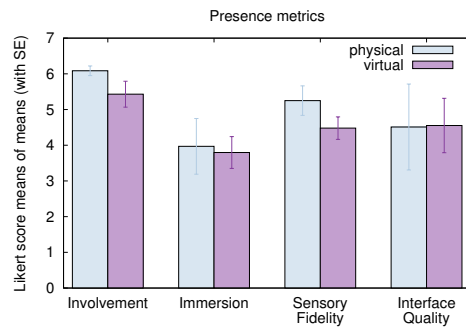


Figure 4.14: Results: presence questionnaire.

Table 4.3: Modal responses to subjective post-experiment questions, marked on a 7-point Likert scale with 1 indicating strong disagreement and 7 indicating strong agreement.

#	Question	mode
1.	The eye tracking glasses felt comfortable.	6
2.	The eye tracking glasses distracted me and hindered my ability to perform my tasks.	1
3.	I preferred the projector search task to the physical search task.	4
4.	I understood what was expected of me in each task.	7
5.	I preferred the physical search task to the projector search task.	4

been measured with a stopwatch (eye tracking data provides clear evidence of active visual search—participants were not simply daydreaming or staring at a fixed point).

Eye movement data also suggests that individuals may have approached the search task in a fundamentally different way over the projected image. Heatmap visualizations of aggregated scanpaths are shown in Figure 4.12. Note that the heavily fixated regions in the four corners represent the possible locations of the boxes—the image chosen for the visualization is one of the layouts used in the experiment, it is used in Figure 4.12 as a representative for visualization of aggregate data from all trials. In the virtual environment, it appears that most viewers may have begun their search near the center, but there is no such obvious trend in the physical environment. What is particularly interesting about this result is that Chandon et al. [2009] found that objects located near the center of the “shelf” can be seen more often but not actually considered (for purchase) in corresponding percentages. Their finding did not fit with other data that suggested that attention correlates fairly well with consideration. Since they did not use an actual shelf in their study (only a projected image), they speculated that this occurred because people might tend to orient their attention to the center of an image during a transition increasing the number of fixations in the area (as is seen in Figures 4.12(b) and 4.13(b)). Our findings suggest that this might not occur as consistently in physical environments.

A key reason for the observed difference in visual search performance may be the fidelity of the projected scene. Although we were careful to control for apparent image size, the projected image clearly differs from its projected counterpart.

The physical scene is much richer in terms of visual elements (color gamut, contrast, and visual depth). The human eye can perceive a very high dynamic range contrast ratio, e.g., 100,000:1, with static perception of about 10,000:1 at any given time. The projectors' lumens rating of 2,500 and contrast ratio of 2,000:1² may have impeded visual search in comparison to what was seen in the physical environment. Projectors are available with greater contrast ratios and spatial resolution (e.g., 12,000:1, 1080p high-definition of the PowerLite home cinema projector), but these projectors are usually “long-throw” projectors and would cause shadow interference problems in the CUshopTM virtual shopping experience being constructed.

What is curious in our study is the lack of perceived differences in response to post-task presence and post-experiment preference questionnaires. Figure 4.14 summarizes the data found in Table 4.2 and shows that while the physical environment appears to have been rated slightly higher in terms of the presence subscales, the differences, along with modal responses to preference, are negligible. It may be that with a larger number of participants the variability would reduce sufficiently to show significance. On the other hand, it is also plausible that brighter projectors with a larger contrast ratio would reduce the difference further still. The projected image may have failed to provide either *physical realism* (in which the image provides the same visual stimulation as scene) or *photo-realism* (in which the image produces the same visual response as the scene), but the image may have contained sufficient *functional realism* (in which the images provides the same visual information) [Ferwerda 2003] to perform the task, albeit consistently more slowly (note that our data analysis pertains to all successful trials).

²<http://www.epson.com/brightlink>

4.2.4 Conclusion

Results were presented from a study comparing consumers' visual behavior when searching for an item located on a virtual or physical shelf. These indicate that the physical environment afforded significantly faster search performance than the virtual projected image. Eye tracking data corroborates this finding by indicating a significantly larger number of fixations made over the virtual shelf.

One reason for the observed difference in visual search performance may be due to the poor fidelity of the projected scene in comparison to the physical shelf. It is possible that the projectors' relatively low contrast ratio impeded visual search. Better projectors and more photo-realistic simulations may improve congruence of eye movement metrics, but one must also consider the overall environment in which the participant is immersed. Advancements in other forms of simulation (automotive and flight for instance) have come not from improvements in visual quality (e.g., resolution, contrast), but from an expanded field of view, realistic motion, and sound. Although visual fidelity will continue to play a significant role in the shopping simulation, the remaining senses must also be addressed. We believe construction of a physical space filled with tactile objects, rich visual elements, and sounds, through which participants navigate, will go a long way toward mitigating the sense of standing in front of a projection screen.

Physical shelves offer a step closer towards physical realism, but they are costly to set up and to stock. If there are sufficient resources, such shelves offer better ecological validity. However, the lack of a perceived difference between the environments suggests that projected replicas may be sufficient for consumer testing (e.g., visual search) since they provide as much visual information. Results suggest that virtual display of the stimulus offers a viable alternative to a physical mock-up so long as one maintains awareness of the potential effect on performance in relation to performance in the field. If the effect is consistent, however, then relative measurements of performance within virtual reality are still likely to be valid.

Chapter 5

The Realization of CUshop™



Figure 5.1: Clemson University's Consumer Experience Laboratory—CUshop™.

The overall goal of CUshop™ is to provide an environment that facilitates the priming of subjects into a shopping frame of mind necessary to generate consumer responses that are similar to that in a retail situation (see Figure 5.1). Empirical results suggested that while a consumer may perform faster viewing physical stimuli (actual packages and shelves), presence is similar with well-designed projector experiments. Thus displays, and particularly large scale (physically realistic) sized displays, may provide useful results with lower cost and faster setup than a similar physical shelf environment. Figure 5.2 depicts the hallway signage and sliding door entrance to the CUshop™ laboratory. The imagery of the signage and design cues (like the sliding doors) begin to communicate that this is not a typical laboratory



Figure 5.2: The CUshop™ outside view and entrance.

or any other normal academic area. The branding, the vibrant and distinct color (green), and repeated use of the logo throughout the space reinforces a familiar retail strategy and feel that is common in customer/brand driven upscale market places. Figure 5.3 shows the brand guidelines, colors, and suggested usage that was developed as part of the Creative Inquiry team’s recommendations.

Figure 5.4 provides four views of the actual CUshop™ environment. The functional aspects of it include:

- four 12’ aisles of high end, reconfigurable shelving that could allow several studies to be conducted simultaneously or for large scale shopping simulations



Figure 5.3: Branding of the CUshop™ to complete the “look & feel” of the area. The idea was “the establishment of a simple icon with minimal color that could be associated with an eye tracking capability (“see you”) and Clemson University (“CU”) while providing a realistic grocery-type feeling of a logo that is not too distracting or overwhelming for the viewer” (PKGSC399, Spring 2011, A. Hurley).



Figure 5.4: The CUshop™ functionally complete on June 16, 2011.

involving multiple aisles—these were powder coated black to provide an up-scale look to the space and to provide a better hiding place for the Tobii IR markers;

- three simulated full size freezer units—real units were omitted due to issues of fitting within the available space, avoidance of possible odor, the aesthetics of natural wood, all attainable at a reasonable cost;
- full height open simulated refrigerator unit that provides a realistic place for item such as cheese, yogurt and other items that are typically on display in an open environment;
- one-way glass observation area so subjects can be monitored without being in the room;

- two areas for point-of-purchase (POP) display studies that have adequate room for larger size (even full pallet) units, but still located within the shopping environment;
- two endcaps with optional 36' or 48' width (both standard in different types of stores) for evaluation of promotional campaigns;
- realistic aisle markers that can be easily re-tasked, but are similar to what might be found in a smaller, upscale market;
- electric shades that can isolate the testing environment from the outside walkway and/or control outside lighting;
- projector screens and short throw projectors on both sides of the central aisle installed in such a way that they are relatively unobtrusively integrated into the shelving environment.

In addition there are several substantial components that were added to further reinforce the proper retail feeling. These include a backlit, high-end CUshop™ logo on the brick wall made of aluminum and plexiglass, decorative panels suspended from the ceiling to mask the original industrial feeling of the room, a large produce stand (artificial, but realistic), and life-sized photographic images on two of the walls



Figure 5.5: Branding of the CUshop™ tertiary items to complete the “feel” of an upscale market place.

depicting a checkout area and deli. Figure 5.5 shows branding components that are being added for promotional purposes (signage and price tag guidelines and a design for shopping bag).

Lessons learned from earlier empirical investigations involved the validity of results obtained using projected systems, and these findings had a direct impact on the integration of a virtual area into a realistic shopping test environment. Originally the shopping environment was meant to remain as it was described in the second experiment (see Figure 4.7), but after analyzing results, it was determined that even though presence was judged to be similar to the real shelves in the experiment, the overall experience could likely be improved. Because of the fundamental nature of projected systems there will continue to be significant limitations related to lighting, contrast and resolution in these situations, but there is a great deal that can be done to improve the rest of the shopping experience while using projectors to display the stimuli. Specific projectors were selected (shown in Figure 5.6) to provide the best combination of viewing experience that include short throw (the ability to be very close to screen eliminating shadows), uniform brightness, and contrast. Figure 5.7



Figure 5.6: The NEC U300X utilizes a combination of an extremely short throw lens and convex mirror arrangement to project an image that minimizes shadowing.



Figure 5.7: Virtual aisle provides life-sized projected image that fills peripheral vision and allows close proximity to screens without shadow interference.

illustrates the setup of the virtual aisle with properly scaled average male and female figures depicting realistic spacing and freedom of movement the subjects will have within the aisle. Integrating the screens and projected images more fully into the shelving units, surrounding the subject on both sides with virtual stimuli, utilizing higher brightness projectors, and controlling the lighting more effectively will further improve the sense of immersion. Other factors such as appropriate signage and recognizable props, auditory cues, and perhaps eventually scent will also be considered.

CUshop™ was completed in June 2011. Before its construction had finished, it had already generated excitement and interest from industry. PackExpo, the largest packaging trade show in the US (with approximately 25,000 visitors), has invited



Figure 5.8: Planned 2,500 sq. ft. exhibit at PackExpo in Las Vegas September 26-28, 2011 that will showcase Clemson University's focus on consumer-centric packaging design methodology. 25,000 attendees regularly visit this trade show.

Clemson University to temporarily move the newly created CUshop™ to the trade show floor (see Figure 5.8 for rough plan of the space). Tradeshow sponsors will fly students and faculty to the event and provide 2,500 square feet of space for the laboratory as well as a promotional area and space to prep subjects. Showcasing the CUshop™ at PackExpo is a unique opportunity to introduce the Institute and the University as well to sample from a large source of participants in two large studies.

Chapter 6

Discussion & Future Work

During the conception, preliminary empirical evaluation, and eventual construction of CUshop™, several interesting issues arose that will lead to additional research opportunities. The most perplexing was in the second study in which scanpaths and heat maps appeared to differ in terms of location and concentration (see Figure 4.13). The projected image showed attention being paid to the center of the screen whereas the the physical shelf did not. There are many possible reasons for this apparent difference including contrast, white point, and other image attributes. There may be other explanations related to the subjects' behavior that are worth exploring. One possibility is the existence of a learned behavior when exposed to a video screen or shelf—a trait developed from frequent exposure (e.g., a search technique that has been learnt when shopping).

One issue that required a fair amount of effort to resolve was reproducing the actual shelf in a physically accurate way. In addition to the perspective differences and color accuracy, there was also a problem with lens distortion. The right image in Figure 6.1 shows obvious barrel distortion imparted by the specific lens used in photographing the shelf. Fortunately this was an easy fix performed by selecting a proper lens profile within Adobe Photoshop to correct the distortion (most modern cameras will record the exact lens used in the metadata of the image file to allow correction in post-processing). The color issue is manageable as it is straightforward to calibrate and/or apply ICC profiles, but taking a picture that results in the right perspective is a challenge and even with careful attention, the results still showed some difference for the real shelf scene. However, it appears that subjects are not overly sensitive to subtle perspective errors as none of them commented on it.

A problem also encountered during the second study was the lack of good light



Figure 6.1: We discovered many logistical and environmental issues in performing eye tracking studies without the proper facilities and procedures.

control. Windows were covered to prevent outside light from impacting the study, but the lab’s lights automatically dim dependent on time of day and several lights could not be turned off (e.g., two of the lights acting as evacuation lights). Considerable effort was exerted to maintain lighting at a level consistent with a retail environment, but a trade-off was necessary to allow reasonable contrast in the virtual image. The image on the left of Figure 6.1 shows how “washed out” the projected image is. This problem will be lessened with the new blinds and full control of the lights, but it will be impossible to ensure a comfortably bright room with reasonable projector performance.

Another issue is the conspicuity of the IR markers when used on projector screen—they are approximately 1” deep and tend to stick out, cast shadows, and act as a distraction to the virtual image. Both of these factors are difficult to reduce, and may be addressed in the future by using a brighter and higher contrast projector, a different projection screen, and redesigned (smaller, and more camouflaged) IR markers. Another possible research topic would be to abandon IR markers all together and use some kind of image marker placed on the virtual shelves (e.g., a bar code or QR code) that can be identified with post-processing of the video stream. If this works it would allow for using the Tobii Glasses with full motion virtual worlds.

In addition to solving these problems for future studies, the three main areas

of research focus that will be addressed in this laboratory in the near future are: validating that the CUshop™ environment can provide results similar to those in a retail store, supplying answers to fundamental questions of how consumers respond to certain packages and other stimuli, and developing virtual and other simpler prototype systems that can be utilized further upstream in the design process to improve the overall efficiency. The validation process should be relatively straight forward and would likely include replicating tasks in both environments to test for similarity of results. Positive results would provide impetus for future research.

There are many possibilities for research pertaining to fundamental consumer behavior and packaging, as suggested below:

- measuring the impact of environment sensory stimuli (sound, light, scent, . . .) on consumer behavior and package selection;
- measuring consumer response to active packaging (light or noise emitting, NFC or QR code usage);
- testing private brand design cues related to top brands;
- measuring the impact of improved virtual environment (sound, field of view, lighting) on subject search characteristics;
- measuring consumer response to color, shape or placement based vs. demographics or product segment;
- developing a methodology and curriculum for teaching consumer evaluation as part of a packaging design workflow.

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