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The Effects of Store Layout on Consumer Buying Behavioral Parameters with Visual Technology

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In this project, we develop a new research methodology that allows the objective measurement of the cognitive and psychophysical reactions of individual consumers to structural changes in realistic store settings. The research methodology combines a new tool for immersive virtual reality display, built recently in the Purdue Envision Center, with a set of objective and subjective measurements of the consumer experience. The purpose of the stage of this research defined in this paper is to examine the effects of different store layout on signal-detection statistics, which take into account both intended purchases (hits) and unintended purchases (false alarms), and provide independent measures of the degree to which a shopper meets their shopping goal (sensitivity) and their strictness or impulsivity in making purchases (response bias). Fifty-seven subjects from Purdue University interacted with a virtual environment modeled on a grocery store to find and select items from a memorized shopping list under a time limit. Measurements were made of the participants' navigational path, the time to reach and search the targeted store for the specified items, and the accuracy (both hits and false alarms) of the selections. Participants were then surveyed by questionnaire on shopping motivations and shopping habits. We tested the same participants in different virtual environments (grid and circular layouts) using identical products in a within-subjects statistical design. Although there are no performance differences between grid and circular layouts exhibited by the subjects, regression analyses of the survey data from the participants show that the hedonic shoppers that enjoy browsing in a store have an increased tendency to make unplanned purchases. Thus, our study demonstrates that the actual habits of these shoppers correspond with their self-assessed motivations, reflecting either a lax or strict criterion in purchase decisions. Moreover, we find that hedonic shoppers are less accurate overall in properly locating targeted items, due to the reported differences in shopping approaches between hedonic and utilitarian shoppers.

Introduction

In this project, the research team developed a new research methodology that allows the objective measurement of the cognitive and psychophysical reactions of individual consumers to structural changes in realistic store settings. The research methodology combines a new tool for immersive virtual reality display, built recently in the Purdue Envision Center, with a set of objective and subjective measurements of the consumer experience. The virtual display is a photorealistic rendering of a virtual mall and store developed through stereoscopic rendering technology. Participants can navigate through the mall and into the store to engage in various shopping tasks (e.g., purchasing items from a predetermined list, browsing, comparing brands and prices, etc.) within a fully immersive environment. During store exploration, measures of a set of objective variables are taken, including navigational path, type, and accuracy of intended purchases; time of purchase deliberation; and biases in purchase decisions. Afterward, participants are surveyed regarding details of their usual shopping habits and their recent experience within the virtual store. Together, the objective and

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subjective measures provide a full picture of buying habits within a tailored shopping environment.

This project was conducted in two stages. The first stage involved three parallel phases: (1) creation of the virtual environment and simulation, (2) creation of a set of objective measurements of shopper behavior and psychophysical measurements of the shopping environment (signal-detection statistics), and (3) development of a set of subjective measures of the shopping experience. The variable manipulated was the use of shopping list by the subject. The purpose of this stage was to test whether the use of a shopping list (Experiment 1) had a significant impact on the signal-detection statistics (i.e. objective variables). We have previously reported the results of the experiment in the first stage. The second stage has two phases: (1) the creation of two types of layout in virtual store (grid and circular), and (2) the creation of a set of objective measurements of shopper behavior and psychophysical measurements of the shopping environment (signal-detection statistics). The purpose of this stage was to examine the effects of different store layout on signal-detection statistics (Experiment 2). The current report will focus on the procedure and results obtained from the second stage.

Background

Signal Detection Theory

Signal Detection Theory (SDT) is a technique for quantifying the ability of observers to distinguish between target stimuli and irrelevant noise in detection, discrimination, or search tasks. The theory has been used previously in the fields of communication engineering, quality control, and perceptual psychology (Green and Swets, 1966; Macmillan and Creelman, 1991). The purpose of the current investigation was to apply signal-detection theory to the study of product-locating behavior. There are four behavioral outcomes derived from signal detection theory: (1) a *hit*, or the selection of an item on the shopping list; (2) a *miss*, or the failure to select an item on the list; (3) a *false alarm*, or the selection of an item not on the list; and (4) a *correct rejection*, the proper refusal to select an item that was not on the list. These four outcomes arise from a combination of a sensory process, an observer's sensitivity or ability to remember the items on the list, and a decisional process, the observer's response bias or general tendency to select and purchase items in a store environment. The four outcomes are used to derive signal-detection statistics that estimate sensitivity separately from response bias (Green and Swets, 1966).

The statistic d' quantifies the sensitivity of responses to targeted (intended) stimuli. It measures an observer's ability to discriminate signal from noise (Synodinos, 1988). In the present study d' is defined formally as:

$$d' = z(H) - z(F) \tag{1}$$

where $z(H)$ is the normalized proportion of hits and $z(F)$ is the normalized proportion of false alarms, with [1- $p(H)$] and [1- $p(F)$], respectively, as the proportion of *misses* and *correct rejections*. In the context of shopping behavior, d' provides a straightforward measure of the deviation from the shopping plan: the number of actual purchases from the set of intended purchases (i.e., hit rate) relative to the number of unintended purchases from the set of all products that compete for the consumer's attention (i.e., false alarm rate). For the purposes of the present project, we keep the number of correct rejections constant for every participant.

The statistic β quantifies an observer's type and degree of bias in making responses. In the context of shopping, it reflects a shopper's general tendency to select items for purchase. One can define β formally as the likelihood ratio of the observer's decision criterion, with the numerator of the ratio indicating the likelihood of the signal distribution at the criterion, and the denominator as the likelihood of the noise distribution at the criterion. Thus, when $\beta = 1$, an observer is unbiased in his or her shopping selections. A shopper with a tendency to make purchases (a lax or liberal criterion) possesses a β value less than one, whereas a shopper with a tendency to refrain from making purchases (a strict or conservative criterion) has a value greater than one. From the point of view of the retailer, shoppers adopting a lax criterion are the most desirable because they tend to have a high rate of buying products on the shopping list, or high hit rate, a high rate of unintended purchases, or high false alarm rate.

Store Layout

In the second stage, we compare sensitivity and response bias between two different types of store layout: grid and circular. As before, we define the hit rate as the selection of exact items on the list. Few researchers have focused on the effects of shopping behavior on spatial layout. Thus, we have no specific prior predictions regarding sensitivity and bias between the two layouts. Levy and Weitz (2004) identify three types of spatial organization: grid, freeform, and circular layout. We chose grid and circular because these schemes are frequently encountered in supermarket environments (Levy and Weitz, 2004), while the freeform/boutique layout, a free-flowing and asymmetric arrangement of displays and aisles, is usually specific to department stores. In this study, the grid layout is defined a rectangular arrangement of displays and long aisles, as shown in Figure 1. The display has multiple shelves that run parallel to one another. The circular layout, often called a "racetrack layout" (Levy and Weitz, 2004), has a circular arrangement of shelves, as shown in Figure 2. The shelves are organized into individual semi-separated areas. This layout is frequently encountered in open areas of grocery stores and supermarkets.

Methodology

Participants

Fifty-seven subjects (13 female, 44 male) from Purdue University participated in the study for course credit. The nature of the procedures were explained fully, and

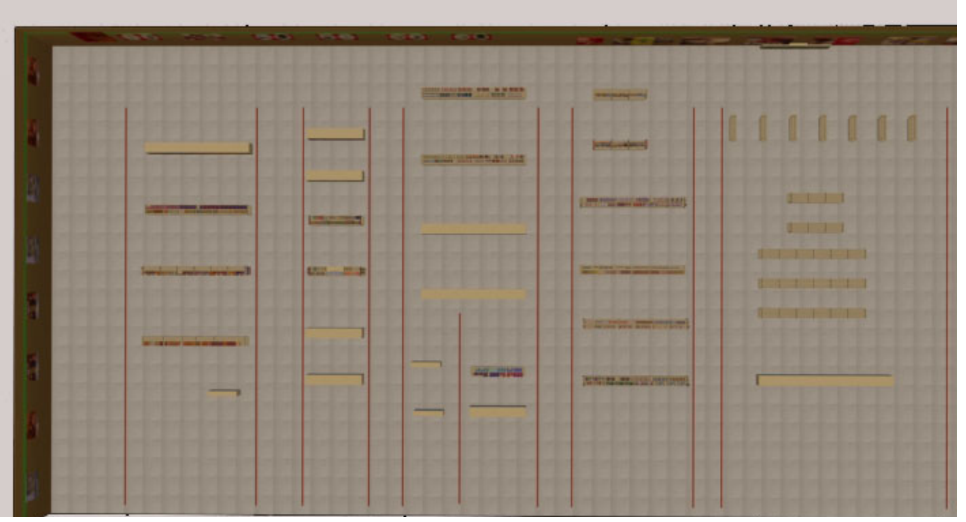

Figure 1.
Grid Layout.

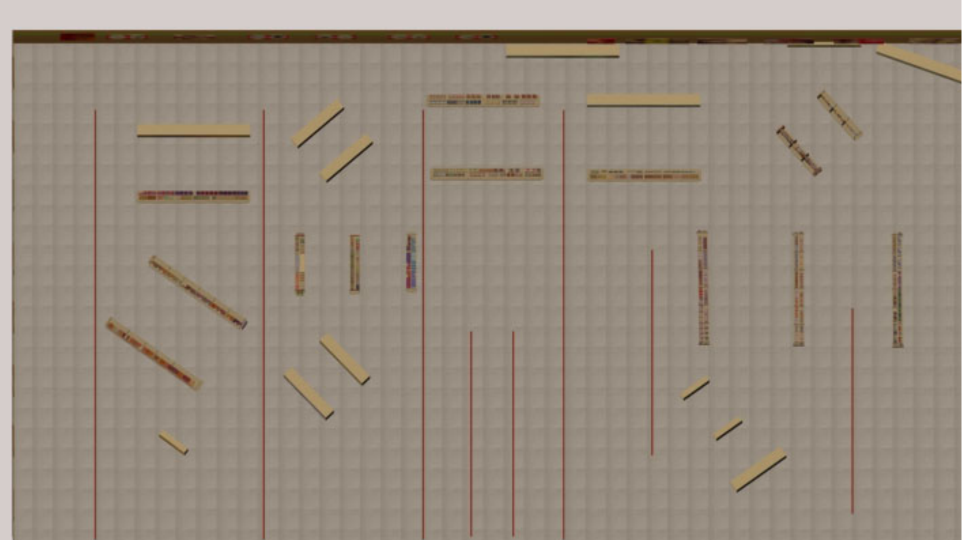

Figure 2.
Circular Layout.

informed consent was obtained from each participant. The Institutional Review Board of Purdue University approved the protocol.

Stimuli, Apparatus, and Procedure

Participants interacted with a virtual environment modeled on a grocery store within a local mall. The virtual store was projected on a tiled wall (VR Theatre configuration). The task of participants was to navigate through a virtual store where they were asked to find and select items from a memorized shopping list under a time limit. Visual search was tested within the grid and circular layouts using a within-subjects design. The order of presentation of the two layouts was counterbalanced across participants. For each layout, participants were given several seconds to memorize a shopping list of 6 items, the list was taken away, and then the participants had ten minutes to find and select the items.

Measurements

Measurements were made of the participants' navigational path, the time to reach and search the targeted store for the specified items, and the accuracy (both hits and false alarms) of the selections. The whole procedure included two sessions. During the first half of the session, participants learned how to navigate the virtual environment and then completed the two shopping excursions.

During the second half of the session, participants were surveyed by questionnaire on shopping motivations and shopping habits. The questionnaire contained nine items, which participants rated using a 7-point Likert scale:

- I usually find great pleasure in shopping;
- Normally, I love to shop with no particular list in mind.
- When I shop, I like to find items quickly and check out as soon as possible;
- Usually I take a list with me when I go shopping;
- I love to browse when shopping;
- When I shop, I tend to impulse buy;
- Shopping is fun;
- Shopping takes too much time; and
- Shopping is important.

Five items regarding shopping motivations adapted from the personal shopping value scale (Babin and Darden, 1994) and shopping strategies (Guiltinan and Monroe, 1980; Zeithaml, 1985) were also administered. Shopping strategies in this case can be defined as "sets of activities that reflect the motives and decision processes governing shopping behavior." (Guiltinan and Monroe, 1980). Four additional items involving shopping habits adapted from the buying impulsiveness scale (Rook and Fisher, 1995) and from shopping strategies (Guiltinan and Monroe, 1980) were provided in the survey instrument.

After completing the questionnaire, participants were asked to evaluate each item on the shopping list for product familiarity using a 7-point Likert scale. These ratings were then summed.

Results

Analysis of Objective Measures

The z-transformed accuracy measures and signal detection statistics were separately subjected to a paired t-test, with store layout as the factor. As can be seen in Table 1, no significant effects of store layout are found for any of the measures. This result suggests that the layout of items in a store has little influence on the accuracy or biases of shopping selections, at least in an unfamiliar store environment. Shopping biases due to store layout may also be expected to emerge as shoppers are given more time for item exploration, in contrast to the shopping deadline imposed in the current study.

Analysis of Subjective Measures

Factor analysis and reliability. An exploratory factor analysis (EFA) was conducted on the rating items for shopping motivations and shopping habits, which were employed in both stages. There are two cross-loaded items in the results, possibly due to the significant relationship between impulse buying behavior and hedonic shopping motivations. Hausman (2000) suggests that hedonic shoppers are more likely to make impulsive purchases. After deleting the cross-loaded items, two factors emerge, as shown in Tables 2 and 3. The first factor represents hedonic shopping motivation, with five items loading onto this factor. The factor is reliable, with a Cronbach's α of 0.86. Unfortunately, the second factor from this analysis is not statistically reliable (Cronbach's $\alpha = 0.189$) and was eliminated from further consideration.

Regression Analysis Between Subjective and Objective Measures. To predict shopping performance from measures of shopping motivation and product familiarity, the objective measures were regressed on the subjective measures. A single regression was performed on each objective measure – d' and β – with results combined from the two experiments, averaged across conditions within experiment. Factor scores for the hedonic factor (Factor 1) of the factor analysis is used as the measure of shopping motivation. The sum of the familiarity ratings on each item in the shopping list is used as the measure of product familiarity.

The results of the regressions of d' on motivation and familiarity are shown in Table 4. The analysis reveals that sensitivity in product-locating behavior can be predicted from the consumers' shopping motivation ($\alpha = 0.1$), with a regression coefficient of -0.642. Specifically, hedonic shoppers are significantly less accurate in locating products than utilitarian shoppers. Product familiarity, however, has no effect on sensitivity.

The results of the regression of β on motivation and familiarity are shown in Table 5. The analysis reveals that shopping motivation significantly influences

Table 1.
Summary of Paired t-test of Signal Detection Measures Under Grid Layout and Circular Layout.

	Mean Grid Layout $n = 57$	Mean Circular Layout $n = 57$	*df* of Model	*t*-value	Sig.
Z(H)	-0.413	-0.251	1	-1.078	0.286
Z(F)	-0.653	-0.674	1	0.156	0.876
d'	0.240	0.422	1	-0.917	0.363
β	2.168	2.682	1	-0.846	0.401

Table 2.
Total Variance Explained by Factors.

	Initial Eigenvalues		
Factors	Total	% of Variance	Cumulative %
Factor 1	3.318	47.394	47.394
Factor 2	1.171	16.723	64.117

Table 3.
Exploratory Factor Analysis and Reliability.

	Factor Loadings	
	Shopping Motivations	*Shopping Habits*
Items	Cronbach's $\alpha = 0.860$	Cronbach's $\alpha = 0.189$
I usually find great pleasure in shopping	0.886	
When I shop, I tend to impulse buy.		0.686
When I shop, I like to find items quickly and check out as soon as possible.	-0.663	-0.386
I usually take a list with me when I go shopping.		-0.741
I love to browse when shopping.	0.771	
Shopping is fun.	0.884	
Shopping takes too much time.	-0.738	

Table 4.
Results of Regression Analysis For d'.

Independent variable	R^2	Coefficient	*t*-value (*p*)
Product Familiarity	0.025	0.018	1.038 (0.301)
Shopping motivation	0.025	-0.239	-2.202 (0.029)

Table 5.
Results of Regression Analysis For β.

Independent variable	R^2	Coefficient	*t*-value (*p*)
Product familiarity	0.039	-0.057	-1.211 (0.227)
Shopping motivation		-0.642	-2.196 (0.029)

response bias ($\alpha = 0.1$). The regression coefficient of shopping motivation is -0.642, indicating that hedonic shoppers are significantly more liberal in their criteria for making purchasing decisions than utilitarian shoppers. Thus, hedonic shoppers have a relatively higher rate of purchasing, selecting more products on the shopping list (higher hit rate) and off the shopping list (higher false alarm rate) than utilitarian shoppers. Again, product familiarity has no effect on response bias.

Conclusions

Signal-detection statistics are useful objective measures that can be applied to questions of marketing and consumer behavior. They provide a more precise assessment of shopping activity by taking into account both intended purchases (*hits*) and unintended purchases (*false alarms*). Moreover, a signal-detection analysis provides independent measures of the degree to which a shopper meets their shopping goal (*sensitivity*) and their strictness or impulsivity in making purchases (*response bias*). In this way, signal-detection theory can provide a more in-depth analysis of the perceptual, personality, and cognitive variables that influence shopping efficiency on the one hand, and purchase tendencies on the other.

In this project, the research team performed signal-detection analysis in the context of a virtual shopping environment. The application of virtual reality systems to the study of advertising and consumer behavior has recently attracted the attention of researchers (Holbrook and Kuwahara, 1999). The advantages of conducting consumer research using virtual environments are many, including research efficiency, strong environmental control, design flexibility, and improved power of parametric statistical tests (Needel, 1998). We exploit these virtues in the current study by testing the same participants in different shopping conditions (e.g., different physical layouts) using identical products in a within-subjects statistical design. Nevertheless, the behavior of participants in virtual and real environments may differ in important ways that can reduce the validity of virtual environments in eliciting normal shopping behavior (Burke et al., 1992). For example, it is conceivable that our failure to obtain performance differences between grid and circular layouts is due in part to a failure to fully mimic a normal shopping experience in the virtual theater. Thus, researchers must be cautious in extrapolating from results obtained in controlled environments, such as virtual systems, to real-world shopping behavior.

The present study also provides some valuable findings on the relations between subjective measures (shopping motivation and product familiarity) and objective shopping indices (sensitivity and subjective bias). The regression analyses show that those hedonic shoppers that enjoy browsing in a store have an increased tendency to make unplanned purchases. Thus, our study demonstrates that the actual habits of these shoppers correspond with their self-assessed motivations, reflecting either a lax or strict criterion in purchase decisions. Moreover, we find that hedonic shoppers are less accurate overall in properly locating targeted items. This can be explained by the reported differences in shopping approaches between hedonic and utilitarian shoppers: the latter are considered more task-oriented and tend to focus on finding a specific product (Dawson et al, 1990).

References

Babin, B. J., and W.R. Darden (1994), "Work and/or Fun: Measuring Hedonic and Utilitarian Shopping Value," *Journal of Consumer Research*, 20 (4), 644.

Burke, R. R., A.B. Harlam, E.B. Kahn, and M.L. Lodish (1992), "Comparing Dynamic Consumer Choice in Real and Computer-Simulated Environments," *Journal of Consumer Research*, 19 (1), 71-82.

Dawson, S., P.H. Bloch, and N.M. Ridgway (1990), "Shopping Motives, Emotional States, and Retail Outcomes," *Journal of Retailing*, 66 (4), 408-427.

Green, D.M. and J.A. Swets (1966), *Signal Detection Theory and Psychophysics*, New York: John Wiley and Sons, Inc.

Guiltinan, J.F. and K.B. Monroe (1980), "Identifying and Analyzing Consumer Shopping Strategies," *Advances in Consumer Research*, 7 (1), 745-748.

Hausman, A. (2000), "A Multi-Method Investigation of Consumer Motivations in Impulse Buying Behavior," *Journal of Consumer Marketing*, 17 (5), 403-419.

Holbrook, B.M., and T. Kuwahara (1999), "Probing Explorations, Deep Displays, Virtual Reality, and Profound Insights: The Four Faces of Stereographic Three-Dimensional Images in Marketing and Consumer Research," *Advances in Consumer Research*, 26 (1), 240-250.

Levy, M. and B. Weitz (2004), *Retailing Management,* 5th ed., Boston: McGraw-Hill.

Macmillan, N.A. and C.D. Creelman (1991), *Detection Theory: A User's Guide*, Cambridge: Cambridge University Press.

Needel, P.S. (1998), "Understanding Consumer Response to Category Management through Virtual Reality," *Journal of Advertising Research*, 38 (4), 61-67.

Rook, D. and F. Robert (1995), "Normative Influences on Impulsive Buying Behavior," *Journal of Consumer Research*, 22 (3), 305-313.

Synodinos, N.E. (1988), "Review and Appraisal of Subliminal Perception within the Context of Signal Detection Theory," *Psychology and Marketing*, 5 (4), 317-336.

Zeithaml, V.A. (1985), "The New Demographics and Market Fragmentation," *Journal of Marketing*, 49 (3), 64-75.