Visual Attention in Consumer Settings

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In order to understand the role of visual attention in consumer behavior, it is important to understand the various time scales of human behaviors and the multilevel cognitive processes that support these behaviors. We will use grocery shopping as an example. The broadest time scale is the lifespan. Small children ride in shopping carts, begging for the treats that catch their eye, such as the colorful Lucky Charms cereal boxes, toys, and the oh-so-close candy in the oh-so-slow checkout line. Teenagers do occasional supplementary shopping for items not found in the pantry or refrigerator, and most adults shop frequently for themselves and their families. Thus, we all have extensive knowledge structures, decision strategies, and visuomotor programs for supporting this essential activity of modern life, and these have been acquired gradually over time from experience mainly outside the classrooms of formal education.

The next time scale is that of planning and executing ordinary purchases, which can be extensive (e.g., several months spent shopping for a new car) or brief (e.g., 30 minutes spent shopping for dinner tonight). This is the time scale of the classic "purchase funnel" models of consumer choice (e.g., AIDA: Attention, Interest, Desire, Action; Hierarchy or Effects: Awareness, Knowledge, Liking, Preference, Conviction, Purchase; see Barry, 1987). These models adopt a single purchase decision as the focal event to be explained and describe a series of other activities that surround this decision. These activities typically last from a few hours (e.g., test driving a car) to a few seconds (e.g., noticing an end-aisle display in the grocery store).

Intuitively, it might seem that we have reached the final level of time resolution for consumer behavior. However, from the perspective of cognitive neuroscience, the next level down is the most important. It is comprised of psychological events that last from .2 or .5 seconds (e.g., noting a posted price) to 1 or 2 seconds (e.g., assessing the acceptability of that noted price). This micro-level of information processing is the critical level for understanding the role of visual attention in supporting all of the broader levels we have described. In a nutshell, attention is the mechanism through which information in the environment is selected for further processing. Without micro-level attention, information in the environment has no effect on behaviors at any other time scale. Attention is the gatekeeper for everything that enters our experienced world.

Attention, Perception, Cognition, and Behavior

There is a broad consensus in psychology and neuroscience about the general flow of information in the environment into and throughout the brain, and how new information is combined with previously processed information (at all time scales) to create our perceived world, guide our actions, and achieve our goals (e.g., Gazzangiga, Ivry, & Mangun, 2013; Purves et al., 2012). Of course, there are many unanswered questions and controversies, but it is useful at the outset to place attention within the broader framework of human information processing. Figure 1 provides a schematic diagram of this consensus model of human information processing.

Insert Figure 1 and Table 1 Here

The environment provides us with a constantly changing assortment of objects and patterns of energy. We have several types of sensory receptors that transduce different types of energy into to neurally coded information. Visual information from the eye projects to several subcortical areas and to visual cortex in the occipital lobe (located at the back of the brain). This information is immediately divided into two pathways: the ventral "what" pathway that connects the occipital to the temporal lobes (which are located at the sides of the brain) and the dorsal "where" pathway that connects the occipital to the parietal lobes (which are located at the top of the brain). The ventral pathway is non-spatial and primarily supports object recognition. The dorsal pathway is retinotopic (i.e., reflects the spatial organization of the visual field that is projected onto the retina of the eyes) and primarily supports object location. Working memory and the selection and control of behaviors are generally ascribed to the frontal lobe of the brain (although the "location" of working memory is somewhat controversial).

Controlled behaviors are designed to achieve specific goals based on perceptions of the current environment and expectations based on knowledge about the world that is maintained in long term memory (e.g., Gabrieli, 1998; Gluck, Mercado, & Myers, 2008; LaBar & Cabeza, 2006). Goal-directed attention prevents most information in the environment and in long-term memory from becoming active in working memory. It allows only the most immediately goal-relevant information to be selected for guiding controlled behavior. In addition to controlled behaviors, many behaviors have become automatic and occur without conscious awareness whenever environmental or memorial information triggers them. Table 1 summarizes the information processing functions of the main brain structures that support visual attention, learning and memory (also see Gazzangiga, Ivry, & Mangun, 2013, and Purves et al., 2012, especially chapters 6 & 7 in both texts).

Overview of the Chapter

In this chapter, we first discuss the relationship between visual attention and eye movements. Then, we examine the psychological and consumer literatures in three, increasingly complex problem domains in visual attention: visual search, scene perception, and navigation. In addition to reviewing the empirical findings across these three domains, we also review quantitative models of visual attention. Finally, we conclude with a few thoughts about the most important directions for future research.

Visual Attention and Eye Movements

Earlier we said, "Attention is the gatekeeper for everything that enters our experienced world." Eye-tracking data is a "gold standard" measure of visual attention. (for reviews see Duchowski, 2002; Holmqvist et al., 2011; Rayner, 1998). Historically, this technology provided measurement methods and data that yielded major breakthroughs in our understanding of reading, which continues today. It has also been a critical source of information in the areas of visual search, scene perception, and spatial navigation in psychology and in the areas of advertising, package design, retail display, and software/website usability in marketing research.

The eye does not work like a camera. Unlike film and digital image sensors that have uniform resolution, the retina at the back of the human eye has a very small, central area of high-resolution, color sensitivity called the fovea (about 2 degrees of visual angle or 8 letters at reading distance). Resolution drops rapidly with distance from the fovea. Large shapes, motion, and the "gist" of a scene are apprehended rapidly everywhere in the visual field. However, high-resolution information requires the eye to *fixate* that information on the fovea (although covert attentional shifts can improve peripheral vision; see below). Because of our need for high-resolution, color information, the eye moves 3 - 6 times per second gathering the information that the brain determines to be to most important, where importance is based on (1) previously fixated information, prior knowledge, expectations, and current goals and (2) the inherent salience of environmental stimuli (see next section). High-resolution information includes the internal details of objects (e.g., facial features) and text (e.g., letters and numbers). Thus, the coherent world we "see" is computationally constructed by the brain from this ongoing, fragmented stream of low-level information.

Goal-Directed and Stimulus-Driven Attention

The contents of working memory are heavily influenced by goal-directed attention processes (which are sometimes called endogenous or top-down); however, stimulus-driven attention processes (which are sometimes called exogenous or bottom-up) can sometimes capture or reorient attention (Corbetta & Shulman, 2002; Corbetta, Patel, & Shulman, 2008; also see Carrasco, 2011; Egeth & Yantis, 1997; Theeuwes, 2010). Some stimulus-driven processes are reflexive and capture attention through subcortical, automatic mechanisms (e.g., the orienting reflex toward especially intense or novel stimuli). However, there is also a cortical stimulus-driven system that interacts with a cortical goal-directed system (see Table 1). Corbetta, Patel, and Shulman (2008) summarize these systems as follows, "A dorsal frontoparietal (or dorsal attention) network enables the selection of sensory stimuli based on internal goals or expectations (goal-directed attention) and links them to appropriate motor responses. A ventral frontoparietal (or ventral attention) network detects salient and behaviorally relevant stimuli in the environment, especially when unattended (stimulus-driven attention). These systems dynamically interact during normal perception to determine where and what we attend to." The key characteristic of the ventral stimulus-driven system is that it monitors salient information that is currently being filtered out by the dorsal goal-directed system, and it interrupts and reorients the goal-directed system when it detects task relevant information that is currently outside of conscious awareness.

For example, a shopper might be examining the various sizes and prices of Extra-Strength Tylenol on a store shelf immediately in front of him. The ventral system might be activated by a large "SALE" in-aisle display and reorient attention to it because saving money is always important, even if it is for some other product. Also, the ventral system is sensitive to "irrelevant" objects that are similar to target objects. Thus, the ventral stimulus-driven system might detect the red store brand products displayed next to Tylenol (a common retail practice) and reorient attention to the adjacent store brand. The shopper would then consciously decide whether or not the store brand was worth further consideration based on information provided by the reoriented dorsal goal-directed system.

The Tylenol example represents a major connecting point of psychological and consumer research on visual attention. In both retailing and advertising, an important goal of marketing actions is to capture attention in the face of competition from external visual clutter and internal consumer goals and expectations. Thus, the distinction between goal-directed and stimulus-driven attention is a major theme in our review.

Covert Attention, Overt Attention, and Eye Movements

In order to connect eye movements to visual attention, it is important to understand covert and overt changes in the location of attention. Even when stimuli are presented so briefly that an eye movement is not possible, people are able to move their attention covertly to different locations in the presented display. The methods through which this result has been demonstrated are beyond the scope of this review (see Carrasco, 2011; Theeuwes, 2010). However, the picture that emerges is that a very rapid, low level system can scan all locations rapidly (possibly in parallel) for certain types of low-resolution information in a stimulus-driven manner. Then, without the eye moving, attention can be covertly reallocated spatially via goal-directed processes to improve resolution in specific locations. Although the improvement for peripheral locations is not so great as foveal fixation, it is enough to rapidly guide where that next fixation should be. Eye fixations are overt, sequential reallocations of attention that are relatively slow, but still occurs 3 - 6 times every second. Subsequent perceptual and cognitive processes that operate at broader time scales are constructed from these low level attention-based building blocks.

Visual Search

One of the simplest functions of visual attention is to guide a search for a specific target object. A moment's reflection reveals that visual search is ubiquitous in our everyday lives. We search for food in our refrigerators, doorways and steps as we walk through rooms, keys and wallets as we prepare to leave home, street names and traffic patterns as we drive, products when we shop, characters within the scenes we view on television; the list is unending. In this section we review the basic findings from research on visual search in psychology and consumer behavior.

Visual Search in Psychology

Classic visual search paradigms in psychology use brief presentations of a set of items that include a target item to be found among some number of distractor items. Presentation is so brief that eye movement is not possible, and search must rely upon covert attention. Success in visual search tasks requires both object recognition (i.e., the ventral "what" pathway) and object location (i.e., the dorsal "where" pathway). In a seminal paper, Treisman and Gelade (1980) reported several critical findings about visual search and proposed Feature Integration Theory to explain those findings. Their paradigm used stimuli that had two visual features: color (e.g., green vs. brown) and shape (e.g., T vs. L). Two tasks are of particular interest. The first task was conjunctive search (e.g., Is a "green T" present?). Feature conjunction is a simplified version of one of the central problems of human vision, called the "binding problem". Given the very low-level, fragmented information that is available in the environment, the viewer must know how to bind specific perceptual features together as coming from a single coherent object. The second task used by Treisman and Gelade was feature-based search (e.g., Is a "T" present?). For the conjunctive task, decision times ranged from under a second to over 3 seconds. Importantly, times increased linearly with the number of distractors (which varied from 1 to over 30), and the slope for positive trials when the target was present was about half the slope for negative trials when the target was absent (about .03 vs. .07 seconds). This is exactly what would be expected if people sequentially search through items by shifting their attention from location to location. That is, on average the target should be found after about half of the items have been examined for positive trials, but only after all items have been examined for negative trials. For feature-based search, decision times were very fast (about .4 seconds) and unaffected by the number of distractors (i.e., slopes were close to zero). The rapid detection of single features is often called a "pop-out" effect, as the target seems to appear quickly and without cognitive effort.

Feature Integration Theory explains these classic results by proposing that features are detected early in the search process by rapid parallel processing that is independent of location. In the featured-based task, this is all that is required. In the conjunction task, focal attention is required so that specific locations can be sequentially examined for the presence of both features. Treisman and Gelade noted, however, that their results depended on the objects being novel and confusable with the distractors. They hypothesized that for familiar objects in familiar contexts, prior experience would lead to goal-directed expectations that would greatly speed up the search process and allow fairly accurate object recognition without sequential search.

Although the both the empirical findings and the theoretical explanations have become more complicated over time, this general idea of sequential, location-specific visual search remains. The overt attention created by eye movements has been found to be very similar to sequential covert attention, and overt attention is more effective than covert attention because eye movements focus the high resolution of the fovea on specific locations (see Carrasco, 2011; Rayner, 1998). Most researchers now believe that sequential visual search (whether overt or covert) is not random, but is guided by the salience of objects, which is determined by a combination of goal-directed and stimulus-driven factors (Corbetta, Patel, & Shulman, 208; Theeuwes, 2010; Wolfe, 1994).

Visual Search in Consumer Behavior

Pure visual search tasks are not common in consumer research. In fact, we know of only one paper in which the task was simply to find a pre-specified target presented among distractors (i.e., van der Lans, Pieters, & Wedel, 2008). Instead, a choice task is often used in which the "target" is the product that the subject would most likely purchase from an offered set of products that are visually displayed. In most cases, the display is a grid format of some sort because such product grids are common in store displays, mail catalogs, and online shopping sites. Thus, the target criteria are personally determined, heterogeneous across subjects, and require more complex decision processes than object recognition. In some paradigms, there is no explicit search task of any sort and subjects are simply asked to view the display as they normally would (e.g., browse a catalog or read a newspaper). Despite these procedural differences, visual attention should guide the ways in which information is acquired from the displays in much the same way as is the case for the visual search paradigms used in psychology, thereby providing a test of external validity for those paradigms. In particular, we will highlight the findings in consumer research that extend our understanding of goal-directed and stimulus-driven visual information processing.

Brand Search Paradigms

Van der Lans, Pieters, & Wedel (2008) presented subjects with a realistic store display of laundry detergents (16 images and 6 different brands that varied in location, number of images, color and package design). On each trial, subjects were asked to locate a specific brand and eye movements were tracked. Response latencies and accuracy was modeled as a function of fixations during search, and fixations were modeled using a Hidden Markov Model (HMM) based on Wolfe's work on salience maps (1994; Wolfe & Horowitz, 2004; see also Liechty, Pieters, & Wedel, 2003, which is discussed in the Quantitative Models section). The HMM has two states: an identification state which determines whether the currently fixated brand is the target brand (local information search), and a localization state that is influenced by stimulus-driven factors (i.e., main effects of color and search strategy) and goal-directed factors (i.e., the interaction of color with brand). Based on these definitions, stimulus-driven factors were found to have twice the effect size as goal-directed factors. It is not clear that the stimulus-driven factors meet the same criteria as are used in the psychological literature. However, the modeling is admirable in its ability to link a variety of attention-related variables via a theory-based stochastic process and thereby estimate the contributions of different components of the process.

Choice Paradigms

Choice paradigms have been used by Chandon, Hutchinson, Bradlow, and Young (2007, 2009), Mandel and Johnson (2002), and Townsend and Kahn (2014). Chandon et al. (2009) used a carefully constructed, fractional factorial design to construct 12 realistic store displays that manipulated area (i.e., number of facings), brands (11 familiar brands and 1 novel brand), location (top vs. bottom and left vs. right), and price. The search task was either choice of a single brand or selection of a set of brands worthy of further consideration. Stimulus-driven factors (especially number of facings) were found to exert a strong influence on number of fixations, but only modest effects on recall, consideration, and choice. Goal-directed factors (especially prior brand usage) exhibited the opposite pattern: a modest influence on number of fixations, but strong effects on recall, consideration, and choice. They also showed that whether or not visual attention affected choice depended on which stimulus-driven factor enhanced attention. In particular, number of facings, left vs. right location, and top vs. bottom location affected choice, but having a central location had no effect on choice (despite having a very large effect on number of fixations). Overall, goal-directed factors exerted a much larger effect on choice than did stimulus-driven factors, which replicated earlier work (Chandon, et al., 2007) that used quantitative modeling of a similar task to estimate relative contributions to choice. However, small short-term effects can result in larger long-term changes in behavior. The small stimulus-driven changes created by in-store marketing on one trip may result in purchase, or at least increased brand familiarity based on in-store consideration. Thus, these changes increase the impact of goal-driven factors for the brand on the next trip, and repeating the purchase cycle can "ratchet up" the small effects into enduring brand loyalty.

These results, combined with those of van der Lans, Pieters, & Wedel (2008), suggest that stimulus-driven factors strongly affect consumer attention, but these large effects on attention translate into only slight "nudges" in purchase behavior. Because purchase is mainly goal-directed, long-term effects will only be achieved when stimulus-driven factors affect goal-driven factors (e.g., a trial purchase evolves into repeated purchases).

Mandel and Johnson (2002) used the images that formed the "wallpaper" of a simulated online store as a stimulus-driven priming manipulation for product choice (i.e., images were related to either price or quality), and attention was measured using clickstream data (i.e., the time stamps on clicks for information of a given type -- price vs. quality -- for a specific product). Novice consumers exhibited priming effects for both looking times and choice frequencies; however, expert consumers exhibited only the choice effect (presumably because they were more efficient at visual information processing).

Using a choice task, Townsend and Kahn (2014) manipulated the number of products in a display (e.g., 8 vs. 27 items in the "assortment") and whether item information was verbal or visual. Similar to the classic results in visual search, total decision time increased with assortment size. However, time per item (as measuring by eye-tracking analyses) was less for large assortments than for small assortments during an initial viewing, and this effect reversed during the choice phase. Perhaps there are efficiency gains from even small amounts of prior experience searching in a display. This efficiency explanation is speculative at this point, and the interactions in the results from these two experiments (i.e., interactions with expertise for Mandel & Johnson and interactions with initial vs. final decision phases in Townsend & Kahn) pose interesting questions about visual attention in paradigms that embed visual search within a more complex task (such as product choice).

Natural Viewing Paradigms

Natural viewing paradigms have been used by Janiszewski (1998) for catalog browsing and Pieters, Wedel, and Zhang (2007) for newspaper reading. In this paradigm, subjects are instructed only to read materials as they normally would. Both papers used eye-tracking data and found effects of stimulus-driven factors on incidental attention. In particular, the area given to target information had a positive effect on attention and the amount of competitive "clutter" had a negative effect. Janizsewski also reported evidence from actual product sales consistent with the hypothesis that attention to catalog items affected consumer purchases.

Scene Perception

Although a fundamental task, most research on visual search has used rather unnatural displays. Even commercial consumer research has mainly used isolated shelf displays and advertisements devoid of their normal environmental context. In this section we review research on the perception of natural scenes in psychology and consumer behavior.

Scene Perception in Psychology

In daily life, individuals devote a lot of time to natural scene perception and can quickly learn the gist of scenes comprised of both high-level semantic knowledge and low-level statistics (Henderson, 1992, 2003, 2007; Olivia, 2005; Oliva & Torralba, 2006; Potter, 1979; Larson et al., 2014). Individuals can readily identify scenes presented for as briefly as 250 ms based on semantic meaning alone (Henderson, 2007, 2013; Henderson & Hollingworth, 1999; Potter, 1976), although this may be impaired by the presence of other tasks that also demand visual attention (Cohen, Alvarez, & Nakayamaciti, 2011; Freedman, Ringer, & Loschsky, 2014).

How individuals process natural scenes has been the subject of much research in psychology and neuroscience. For example, in psychology, scene perception research has examined the processing of both coarse (low-resolution) and fine (high-resolution) information (Oliva & Schyns, 1997, 2000; Schyns & Oliva, 1994). Neuroscience studies using fMRI have identified the parahippocampal place area as being critical for identification and habituation to changing viewpoints during scene processing (Epstein, Graham, & Downing, 2003; Epstein, Higgins, & Thompson-Schill, 2005; Epstein, 2005, 2008).

Natural scene perception may be influenced by goal-directed factors, as well as stimulus-driven factors. These factors contribute to how individuals attend to different areas of scenes and identify objects within scenes.

Goal-Directed Influences Underlying Scene Perception

Early research in scene perception focused on how the goal-directed semantics or "informativeness" of scenes can influence visual attention. It was speculated that visual attention to works of art, for example, may depend on prior experience, and that individuals may look at parts of a scene strategically based on interest or pattern (Buswell, 1935). This was empirically verified in studies that measured and manipulated the informativeness of art pieces, which was correlated with people's eye movements while they viewed the art. People tend to look longer, more often, and earlier at more informative regions of scenes, and also exhibit longer-amplitude saccades (Antes, 1974; Loftus & Mackworth, 1978). However, we note that work following these investigations was unable to replicate many of these results (De Graef et al., 1990; Henderson & Hollingworth, 1999; Hollingworth & Henderson, 1998), so the role of informativeness in scene perception is still open for further research.

People's accuracy and speed when identifying objects in scenes can be decreased by knowledge-driven semantic and structural violations. Such violations may include scene jumbles, as well as unusual sizes or spatial arrangements of objects (Biederman, 1972; Biederman, Mezzanotte, & Rabinowitz, 1982; Henderson, 1992). Research on the effects of these violations lend support to the schema hypothesis, in which a scene's meaning activates relevant knowledge about what exists in a scene, which in turn influences object identification (Biederman et al., 1982; Henderson, 1992). However, more recent work has failed to replicate the results supporting the schema model (Vo & Henderson, 2009), and researchers have suggested alternative explanations such as a priming model in which scene knowledge can change individual sensitivity for judging an object's presence, and a model in which scene knowledge and object identification do not interact (Henderson & Hollingworth, 1999).

Researchers have also investigated the effects of goal-directed factors such as prior exposure and task demands on visual attention (Hayhoe & Ballard, 2005; Land & Hayhoe, 2001). Even brief exposure to a scene, such as a prime of the spatial layout, may inform judgments and speed up response times (Sanocki & Epstein, 1997). Where people look also depends on task goals. For example, individuals look at clothing and furniture when asked to remember the clothing in a painting, but they look at faces when asked to estimate ages of the people in a painting (Yarbus, 1967). While performing everyday activities, like making a sandwich, people tend to fixate on the relevant task objects at each step of the task, and fixations precede actions, with frequent look-ahead fixations (Land & Hayhoe, 2001; Land, Mennie, & Rusted, 1999). Task instructions can also modulate where people look and for how long (Sullivan et al., 2012; Torralba et al., 2006). For example, drivers in a virtual environment will fixate longer and more often on either the leader car or speedometer when asked to follow the leader or maintain a specific speed, respectively (Sullivan et al., 2012). Pedestrians fixate more on people who are on a collision course with them, suggesting that individuals learn where in the scene is valuable to look and allocate attention based on these demands (Jovancevic-Misic & Hayhoe, 2009).

Stimulus-driven Influences on Scene Perception

Different research streams have argued for the importance of stimulus-driven features in scene perception. One approach in particular is to model natural scene statistics such as color and spatial orientation (Oliva, 2005; Torralba & Oliva, 2003), which are thought to be relevant to perceptual tasks such as image representation, object identification, and estimating spatial distances (Geisler, 2008). “Visual crowding” or failure to properly detect a target amongst distractors may be due to saccades interrupting the process of acquiring scene statistics (Nandy

& Tjan, 2012). Faster saccades seem to be correlated with attention to incorrect distractors and are thought to be stimulus-driven, while slower saccades are more accurate and seem to be goal-directed (Van Zoest, Donk, & Theeuwes, 2004). Natural scene statistics can also be used to determine depth based on convexity and concavity (Burge, Fowlkes, & Banks, 2010), as well as to predict saliency (Tkacik et al., 2010).

Researchers have developed models to predict where people look based on the comparison of different regions within a scene. For example, one model incorporates saliency-maps within the environment based on how feature maps of objects in scenes differ from neighboring areas (Itti, Koch, & Niebur, 1998; Itti & Koch, 2001). This setup relies on a center-surround system akin to that of the earliest stages of vision in the retina and primary visual cortex (Purves et al., 2013). The contextual guidance model incorporates both goal-directed and stimulus-driven factors, with scenes processed by a local pathway of low-level scene elements that form a saliency map (Koch & Ullman, 1985; Rosenholtz, 1999), as well as a global pathway based on priors or more holistic assessments (Torralba et al., 2006).

Finally, we review how specific scene characteristics such as color, luminance, clarity, and number of objects can affect scene identification. Coloration can enhance scene identification relative to greyscale, while abnormal coloration may slow identification (Oliva & Schyns, 2000). However, the benefit from color cues may be limited to specific scenes like seascapes, as opposed to urban scenes, for example (Rousselet, Joubert, & Fabre-Thorpe, 2005). Researchers have also suggested that color may illusorily bolster confidence during target image identification (Yao & Einhauser, 2008). Studies in which subjects viewed scenes of varying luminance showed that fixation length increases as luminance drops (Henderson, Nuthmann, & Luke, 2013). Factors such as image clarity and blurring can also affect where people look and for how long, depending on the visual task (Enns & MacDonald, 2013). Studies have also shown that increasing the number of objects in a scene results in decreased fixation duration and saccade length (Unema et al., 2005).

Scene Perception in Consumer Behavior

In this section we examine a few particular types of scenes within consumer behavior, namely advertisements and shopping assortments, both of which have received considerable attention in the consumer behavior and eye-tracking literatures. Research findings regarding visual attention to advertisements and assortments have been consistent with the general scene perception literature from psychology. Individuals are able to categorize ads even with exposures as low as 100 ms, and may rely on coarse details and color during ad recognition (Pieters & Wedel, 2012; Wedel & Pieters, 2015). Researchers have used eye-tracking to examine visual attention to product assortments. Eye fixations during a grocery trip may be broken down into multiple stages, including orientation, evaluation, and product verification (Russo & Leclerc, 1994). More recent work has examined how consumers view product-by-attribute matrices (Shi, Wedel, & Pieters, 2013) and choice-based conjoint cards (Yang, Toubia, & de Jong, 2015). We separate the remaining consumer behavior literature on scene perception into research about the goal-directed factors that influence how people browse and evaluate advertisements and assortments, and the stimulus-driven factors that affect these processes.

Goal-Directed Factors Underlying Consumer Scene Perception

We examine attention to goal-directed factors and how they shift attention, starting with task goals. Similar to how task-based consumption goals may shift attention to specific elements of a scene (Land & Hayhoe, 2001; Land, Mennie, & Rusted, 1999; Hayhoe & Ballard, 2005; Sullivan et al., 2012), goals and expectations for advertisements and assortments can affect where and how people look. Different goals such as ad memorization or product learning/evaluation may influence gaze duration on different parts of ads (Pieters & Wedel, 2007), as well as how consumers switch between local versus global processing, defined by long vs. short saccadic amplitudes, and short vs. long fixations, respectively (Wedel, Pieters, & Liechty, 2008). Out-of-store marketing factors such as prior product experience, product market share, shopper education, and age have been shown to influence product evaluation and whether a product is noticed when shoppers view product assortments within a grocery store (Chandon et al., 2009).

Just as in the psychology literature, violations of prior expectations about an assortment can influence people's perceptions. For example, cutting highly-preferred or expected items can diminish perceptions of assortment variety and even lead to decline in sales (Broniarczyk et al., 1998; Boatwright & Nunes, 2001; Borle et al., 2005). In general, consumers seem to form expectations about assortment sizes and product organization, which can vary by past experience and individual-level product familiarity and expertise. This can help or hurt consumer satisfaction depending on whether or not expectations are met or product arrangements are congruent with consumer goals (Diehl & Poynor, 2010; Morales et al., 2005; Poynor & Wood, 2010).

Even certain positions within assortments can receive different amounts of attention. Shelf position and number of facings influence what products people notice (Chandon et al., 2009). Much work in retailing supports the notion that central positions receive more visual attention during browsing and are desirable for sales (Atalay et al., 2012; Dreze, Hoch, & Park, 1994). Central gaze and selection bias may be due to a mixture of goal-directed and stimulus-driven effects. For example, people could possess priors about where to attend to in a scene (i.e.

believing center options to be more popular), which could lead to visual preference for center areas (Hutchinson & Turk-Browne, 2012; Torralba et al., 2006; Valenzuela & Raghubir, 2009).

Stimulus-driven Factors Underlying Consumer Scene Perception

Similar to research on saliency maps, (Itti & Koch, 2001; Torralba et al., 2006), it has been shown that stimulus-driven factors can create large variation in where consumers look while shopping. Assortment size and presentation style can influence what consumers see and how they judge assortments. For example, in specific contexts, perceived variety increases when assortments are organized (e.g., flavors of jellybeans are separated by color), but not when they are disorganized (Kahn & Wansink, 2004). In other contexts, organized assortments are perceived to have more variety only when shoppers are also engaging in a choice-based task (Hoch, Bradlow, & Wansink, 1999). Visual (as opposed to verbal) presentation of assortments may increase perceived variety, but also increase perceived complexity (Townsend & Kahn, 2014). Thus, there may be contributions to perceived variety from both contextual modulation and stimulus-driven factors (Torralba et al., 2006).

Color organization of an assortment may also shape how much time individuals spend on different parts of the assortment. In a mobile eye-tracking study, shoppers looked at more SKUs in regions that had sharper color blocks (Weingarten, Kahn, & Hutchinson, in preparation). This result may emerge due to two additive mechanisms. First, the enhanced visual contrast of sharper color blocks may promote greater figure-ground separation (Pinna, 2010; Pinna, Brelstaff, & Spillman, 2001; Pinna & Tanca, 2008; Pinna, Werner, & Spillman, 2003; Von der Heydt & Pierson, 2006). Since each section is more clearly distinct from its neighbor, consumers may attend to the regions that have heightened salience (Atalay et al., 2012; Chandon et al., 2009). Second, color blocking may make it easier for consumers to locate target items amongst distractors (Bauer, Jolicoeur, & Cowan, 1996; D'Zmura, 1991; Dhar, 1997). These results point to simple, actionable strategies for arranging assortments to increase perceived variety and visual attention (Geisler, 2008; Shevell & Kingdom, 2008; Weingarten, Kahn, & Hutchinson, in preparation).

Spatial Navigation

Arguably, the most complex area of visual attention is spatial navigation because it embeds search tasks in natural environments with concurrent, dynamic processes for navigating in those environments. However, this is the area of greatest evolutionary value. Hunting and gathering is not possible without seeing and walking. In this section, we review the basic findings from research on spatial navigation in psychology and consumer behavior.

Spatial Navigation in Psychology

Contrary to the position of early behavioral theorists, spatial navigation is not simply a result of stimulus-response learning. The results of Tolman's (1948) rat studies, in addition to subsequent work with humans, suggest that they may possess a cognitive map or spatial representations of their environment that grows from travel experience (Lew, 2011; Tolman, 1948; O'Keefe & Nadel, 1978; Wolbers & Hegarty, 2010; Moar & Carleton, 1982). Results from studies in which participants physically navigate routes suggest that people can represent multiple target destinations and routes simultaneously (Levine, Jankovic, & Palij, 1982).

Landmarks and Spatial Navigation

Some research in spatial navigation examines how individuals use landmark cues (Chan et al., 2012; Epstein & Vass, 2014), and may rely heavily on landmarks during navigation without actually having a geometric representation of the world (Foo et al., 2005). Individuals attend to and use landmarks at decision points, such as at the end of a hallway, more than landmarks that occur between decision points (Hamid et al., 2010). Similar results are found for perceptually salient landmarks (Miller & Carlson, 2011). These results are supported by fMRI evidence suggesting that found increased parahippocampal place area activation for decision-point landmarks compared to non-decision-point landmarks (Schinazi & Epstein, 2010).

Landmarks vary in usefulness based on whether they provide orientation information or precise position information (Ruddle et al., 2011; Steck & Mallot, 2000), and whether they serve as beacons or associative cues (Chan et al., 2012; Ruddle et al., 2011; Waller & Lippa, 2007). Studies in which participants navigate virtual environments showed that beacon landmarks facilitate faster learning of route information than associative cue landmarks (Waller & Lippa, 2007). In addition, landmarks may not always be useful if street information is vivid enough (Tom & Tversky, 2012).

Motion and Spatial Navigation

Both visual and motion-based cues can contribute to cognitive maps and spatial navigation. Research has shown that studying maps improves people's ability to judge Euclidean distances to rooms in a building, while physical navigation and movement experience result in better route distance estimates and fewer errors when orienting to target locations (Thorndyke & Hayes-Roth, 1982; Klatsky et al., 1998). These results suggest that motion may be important in determining position. In studies where participants browsed real or virtual reality environments, it was found that motion may be a sufficient cue for navigation with degraded visual information (Ruddle & Lessels, 2006), and can contribute to cognitive maps even when visual cues go completely dark (Tcheang, Bulthoff, & Burgess, 2011).

Spatial Navigation in Consumer Behavior

Recent experimental work within the consumer behavior literature investigates how consumers navigate their shopping environment, and how navigation influences purchase decisions. Park, Iyer, & Smith (1989) found that low store familiarity and time pressure decreased shopping success for planned purchases, and low familiarity increased unplanned purchases when time pressure was low. It is important to note that planned purchases necessarily depend heavily on goal-directed attention, while in-store marketing designed to increase unplanned purchases depends heavily on stimulus-driven attention.

Some research suggests that while the store environment is not optimally traveled, consumers are not too far off in some respects. Using the shopping cart data from Sorensen (2003), Hui et al. (2009) compute the shortest path that shoppers could have taken in the store, given their purchases, and find large deviations (69%) from optimal paths calculated using algorithms for the traveling salesman problem (Lawler, 1985). Despite these deviations, the order in which consumers browsed items based on what they bought was actually close to optimal (under 20% deviation), implying that while shoppers do not use perfect navigation, their behavior is much closer to optimal than to random navigation.

Researchers have used RFID markers to test other hypotheses regarding in-store navigation. Data from a sample of a few hundred shoppers at a grocery store show that more unplanned movements in a store are associated with more unplanned purchases. Simulating the effect of repositioning product categories revealed a potential benefit to creating more traveled distance and unplanned purchases (Huang et al., 2013).

Researchers have also analyzed data from videos of shopping trips to provide descriptive results about in-store shopping behavior in relation to shelf display distances, product locations, and number of displays. Smaller distance from displays results in more unplanned purchases, categories closer to planned purchase categories receive more unplanned purchases, and fewer displays examined by the shopper lead to more unplanned purchases (Hui et al., 2013).

Quantitative Models of Visual Attention and Decision Making

A recent trend in consumer research has been to model visual attention quantitatively. In this section, we focus mainly on the consumer literature, but also identify areas of overlap with psychology, economics, and artificial intelligence.

Models of information acquisition during choice

Rational models of choice assume that consumers are complete-information utility maximizers (Guadagni & Little, 1983). However, MouseLab[1] and eye-tracking studies that measure attention have demonstrated that people don't always look at all available information before making a choice (Bettman & Kakkar, 1997; Reutskaja et al., 2011). Information acquisition imposes a degree of cognitive load or "cost of thinking," and it is unrealistic to assume that decision makers have unlimited cognitive capacity (Payne, Bettman, & Johnson, 1993; Shugan, 1980). Alternative models of "bounded rationality" have been proposed to explain how people may use simplified choice rules or heuristics when making decisions (Gilbride & Allenby, 2004; von Neumann & Morgenstern, 1947; Payne, Bettman, & Johnson, 1993; Simon, 1955). For example, the satisficing choice rule states that consumers sequentially evaluate choices until one is found to be satisfactory on all attributes, and accounts for the observation

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[1] Before the development and widespread use of eye-tracking in consumer behavior research, techniques such as MouseLab (Johnson et al., 1989) and information booklets (Bettman & Kakkar, 1997) were used to trace consumer search and information acquisition during purchase decisions. MouseLab is a classic method that measures attention by having individuals click on product information cards on a computer screen to reveal information about the products (Johnson et al., 1989). MouseLab has been used by researchers to study choice strategies, such as adaptive decision-making according to the effort-accuracy framework (Bettman et al., 1993).

that even in eye-tracking lab studies that present relatively small numbers of options, people do not always consider all options (Reutskaja et al., 2011; Stüttgen, Boatwright, & Monroe, 2012).

Visual attention is not evenly distributed among choices (as a rational model would predict when prior knowledge is low). It has been shown that manipulating visual attention can influence preferences, and vice versa. Gaze cascade is the phenomenon in which eye fixations gradually shift towards the alternative that is ultimately chosen as the decision time approaches. Conversely, preferences can be biased by showing one of the alternatives for longer durations. People have demonstrated gaze cascade and duration bias while choosing between attractive faces (Shimojo et al., 2003), as well as snack foods and posters (Armel, Beaumel, & Rangel, 2008). However, duration bias was not replicated in an 8-alternative choice task between random black and white photos (Glaholt & Reingold, 2009), suggesting more complicated processes may occur for more complex tasks. In marketing, gaze cascade was demonstrated in an eye-tracking study where subjects paid increasing attention to the chosen option among different brands in a grid display (Atalay et al., 2012).

Although the precise direction of causality in the relationship between preferences and visual attention remains unclear, these findings lend validity to several alternative models of choice that take information processing into account. More extensive reviews of the models we discuss here can be found in previous work (Ratcliff & Smith, 2004, Bogacz et al., 2006, Ratcliff & McKoon 2008, Otter et al. 2008, Orquin & Mueller Loose, 2013). These models fall under the umbrella category of sequential sampling models, which are based on the assumption that the decision maker accumulates bits of information through sequential sampling over the course of the decision making process, with a choice being made once enough evidence has been accumulated in favor of one of the alternatives (Townsend & Ashby, 1983). The sequential sampling process has a natural fit with information acquisition through visual attention, and has been applied by many researchers in psychology and consumer neuroscience.

One subset of sequential sampling models is the race model (or Poisson counting model), which borrows much of its conceptualization from the study of neural networks. Race models were first applied to perceptual identification and recognition memory tasks in order to account for the psychological processes that result in different reaction times and accuracy (Townsend & Ashby, 1983; Van Zandt, 2000; Smith & Van Zandt, 2000). The model has been shown to outperform traditional thought-listing methods in predicting attitudes towards ads in a belief verification task, using choices, reaction times, and confidence ratings as dependent variables (Huang & Hutchinson, 2008). Race models can also be extended to incorporate inhibitory competition between alternatives and memory decay or “leaky” accumulation. The leaky accumulator model was used for a visual perception task in which subjects identified whether a tilted rectangle was longer on the upper left or upper right hand side (Usher & McClelland, 2001).

Decision field theory (Busemeyer & Townsend, 1993) gives us a closely related model in which evidence accumulation is modeled as a continuous random walk process rather than a discrete Poisson process. The continuous model can incorporate the time it takes to sample and process each piece of incoming evidence, determined by the alternative’s relative valence. Decision field theory has been used to explain violations in assumptions of rational decision-making, including preference reversals and decision times during gambles. A multi-alternative extension has been used to account for the similarity, attraction, and compromise effects (Roe, Busemeyer, & Townsend, 2001).

Another class of sequential sampling models are drift diffusion models, which were first applied in psychology to model memory retrieval during object recognition tasks (Ratcliff, 1978). Drift diffusion models involve a single accumulator and are generally limited to binary choices due to computational complexity (Ratcliff & Rounder 1998, Ratcliff et al. 1999, Ratcliff & Smith, 2004). A consumer's relative preference for the two options drifts constantly towards the preferred option until it reaches a decision threshold. Drift diffusion models have been applied to binary visual perception tasks such as brightness and color classification (Ratcliff & Rounder, 1998). The attentional extension of the model specifies drift rate as dependent on the difference in the inherent preferences of alternatives, with the sign of the drift rate depending on which alternative the decision maker is actually looking at. The model can account for accuracy and reaction times of binary choices between snack foods (Krajbich, Armel, & Rangel, 2010), decisions under high and low time pressure (Mormann et al., 2010), buy-no-buy decisions (Krajbich et al., 2012), and trinary choices. However, it is computationally difficult to extend the model further to more options, for which the same processes may also not apply.

Although there is debate over how visual attention is related to alternative value processing, some evidence comes from findings in neuroscience. Subjects in an fMRI scanner chose between pairs of snacks, and visual attention was exogenously manipulated by asking subjects to alternate their attention between the options (Lim, O'Doherty, & Rangel, 2011). Inherent preference for the fixated option was positively correlated with activity in the ventromedial prefrontal cortex (vmPFC) and striatum – areas of the brain established to be involved in choice value computation (Gold & Shadlen, 2007). Further evidence that evaluations are being made at the visual fixation level comes from studies demonstrating the speed of visual saccades and evaluations during choice (Mormann, Koch, & Rangel, 2011; Milosavljevic et al., 2011). Finally, a recent eye-tracking study demonstrates that during gambling choices, early fixations are guided towards areas with new information that may reduce uncertainty about value, while later visual attention is guided by the expected value of the options (Manohar & Husain, 2013). Furthermore, preference reversals between different contexts of risky choice (i.e. choosing between two gambles vs. bidding on single gamble) have been shown to be accompanied by changes in attention to different attributes of the choices (Kim, Seligman, & Kable, 2012).

Models of dynamic information search

The models discussed thus far assume a random process of sampling information. However, for more complex tasks, it is less realistic to assume that information sampling is random. There may be systematic patterns that vary across individuals and across consumption goals. In the marketing literature, it has been shown that consumers tend to process attribute information in the earlier stages of decision-making, and then brand information later on (Bettman & Park, 1998). Earlier we described the results of Russo and Leclerc (1994) for supermarket shopping. Eye fixations follow a three-stage pattern: orientation, evaluation, and verification. Consumers also exhibit systematic eye fixation patterns when viewing print ads. Fixations move from large print to small print to pictures (Rayner et al., 2009), and certain brand elements tend to transfer attention more to other elements (Pieters & Wedel, 2004). Similarly, Gilchrist and Harvey (2006) found that regular grid-like displays (compared to random displays) generated generated more horizontal saccades than vertical saccades, but even when the display was disrupted scan paths exhibited a systematic component.

Other work has modeled how previous fixations influence subsequent fixations in a probabilistic way. Research on natural scene viewing supports the existence of alternating local and global search periods, with statistical dependencies between successive eye movements (Tatler & Vincent, 2008). This work is supported by findings from neuroscience that different brains areas control global and local attention. The posterior parietal cortex (PPC) globally directs visual attention towards regions of interest in a scene, while the inferotemporal cortex (ITC) is involved in local exploration, recognition and identification of objects (consistent with the "where" and "what" pathways discussed earlier; Itti & Koch, 2001). The transitions between local and global search states have been explicitly captured using hidden Markov models (Liechty, Pieters, & Wedel, 2003). A recent eye-tracking study modeled search among products in a shelf display as a satisficing choice process, with local (within-brand) and global (across-brand) search states in an HMM (Stuttgen et al., 2012). Other eye-tracking work has used HMMs to capture transitions between different search strategies within product-by-attribute matrices (Shi et al., 2013) and to model local and global transitions within scan paths of search engine results (Shi & Trusov, under review).

As discussed earlier, work in neuroscience has also identified that goal-directed attention is controlled by the dorsal frontoparietal network. This can be over-ridden by the ventral frontoparietal network, which is specialized for stimulus-driven attention and detecting salient and unexpected – but still behaviorally relevant – stimuli (Corbetta & Shulman, 2002; Corbetta, Patel, & Shulman, 2008). Goal-directed and stimulus-driven attention can be exogenously manipulated using search task instructions, resulting in different search patterns among consumers, as measured via eye-tracking for online and in-store shopping (Lu & Hutchinson, in preparation). This research modeled landing page information search as a two stage process in which the consumer first decides whether or not to exit the page by clicking on a link and then, if exit is not chosen (i.e., visual search continues), the next fixation location on the page is chosen.

The manipulation of interest was whether the shopping instructions encouraged a strict focus on the stated goal (utilitarian instructions) or encouraged reorientation (hedonic instructions). The results revealed eye fixations and choice behavior consistent with the predicted levels of goal-directed and stimulus-driven attention, and estimated model parameters showed that the search was more product focused (vs. exiting to a new, goal-related page) and hedonic attributes were more important in the hedonic condition. Moreover, the price coefficient was positive in the hedonic condition (indicating price-quality inference) and negative in the utilitarian condition (indicating a value-for-the-money orientation).

Directions for Future Research

Our review reveals that the research literatures in psychology and marketing have been surprisingly independent, despite the obvious fact that they purport to investigate essentially the same phenomena. Thus, we believe that the greatest opportunities exist in three areas. First, much consumer research on visual attention has been rather descriptive and focused on important applied problems (e.g., the extent to which in-store marketing or advertising can capture attention, reorient attention, and affect consumer choice). This research will benefit for more careful attention to the more theory-based models being developed in cognitive neuroscience. Second, although many (arguably most) areas of psychological vision research have developed important quantitative models, consumer research appears to be leading the way in developing quantitative models that combine attention and decision making. We believe both fields are poised for an era of productive "cross-fertilization." Finally, eye-tracking technologies have advanced tremendously in recent years and at the same time decreased in cost. Right now this may be the area of greatest overlap between psychology and consumer research. Field research using eye-tracking glasses to examine real-world shopping behavior (which combine visual search, scene perception, and navigation) seems to be an area for which the interests of the two fields are most aligned.

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TABLE 1. Critical Brain Structures for Attention, Learning, and Memory*

Information Processing Functions	Brain Structures
Representation of low-level visual features	Occipital cortex (V1-V4)
Object location ("Where?")	Dorsal occipitoparietal pathway (especially PPC)
Object recognition ("What?")	Ventral occipitotemporal pathway (especially ITC)
Working memory, goal selection, & executive control	Prefrontal cortex
Goal monitoring & executive monitoring	Medial frontal cortex (especially ACC)
Goal-directed (endogenous) attention	Dorsal frontoparietal pathway (especially FEF & IPS)
Stimulus-driven (exogenous) attention	Ventral parietofrontal pathway (especially RTPJ & RVFC)
Reflexive attention	Subcortical (especially SC)
Navigation and scene processing	Parahippocampal place area
Declarative memory (episodic and semantic)	Medial temporal cortex (especially H), middle diencephalon (especially AT), neocortex (especially MPFC)
Skill learning	Basal ganglia
Classical conditioning	Dopamine system, cerebellum

* These general correspondences neglect many details and system interconnection. They reflect common summaries in cognitive neuroscience texts (Ganzzaniga, Ivry, & Mangun, 2013; Purves, et al., 2012; also see Glimcher & Fehr, 2014).

KEY:
V1-V4: primary visual cortex
ACC - anterior cingulate cortex
FEF - frontal eye field
IPS - intraparietal sulcus
RTPJ - right temporoparietal junction
RVFC - right ventral frontal cortex
SC - superior colliculus
H - hippocampus
AT - anterior thalamus
MPFC - medial prefrontal cortex
PPC - posterior parietal cortex
ITC - inferotemporal cortex

Figure 1. A "consensus" model of attention, perception, cognition, and behavior