Neuroeconomic Studies in Industrial Organization:

Brand, Advertising and Price Effects on Consumer Valuation and Choice

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Abstract. Neuroeconomics makes use of new data and tools from neuroscience to enrich the study of economic decision-making. This chapter introduces neuroeconomic methods and surveys a number of contributions to the literature regarding brain responses to brands, advertisements, pricing and product characteristics. These contributions rely primarily on functional magnetic resonance imaging (fMRI) although electroencephalography (EEG) and other methods are also used. Industries represented in the survey include beverages (cola, wine, beer, coffee, and milkshakes); artwork; music; magazines; handbags; televisions; and sunscreen as well as anti-smoking advertisements. Some of these studies move beyond identification of brain regions associated with advertising, for example, to using brain activity to predict individual choices and even the behavior of the population at large.

Keywords: neuroeconomics, brand names, advertising, neuroscience, fMRI

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1.0 Introduction

Neuroeconomics draws from economics, psychology and neuroscience to shed light on how people make choices. Neuroscience allows us to observe brain and other physiological activity linked to utility, decision-making processes and outcomes.

The definition and measurement of utility is not a new goal for economists. Colander (2007, p. 216) documents that as early as 1881, "Edgeworth argued that utility was directly measurable and that new developments in 'physio-psychology' would make it possible to develop a 'hedonimeter' that would allow economists to develop a firm physiological underpinning of utility." In Edgeworth's (1881, p. 101) words:

> ... let there be granted to the science of pleasure what is granted to the science of energy; to imagine an ideally perfect instrument, a psychophysical machine, continually registering the height of pleasure experienced by an individual, exactly according to the verdict of consciousness, or rather diverging therefrom according to a *law of errors*. From moment to moment the hedonimeter varies; the delicate index now flickering with the flutter of the passions, now steadied by intellectual activity, low sunk whole hours in the neighbourhood of zero, or momentarily springing up towards infinity. The continually indicated height is registered by photographic or other frictionless apparatus upon a uniformly moving vertical plane. Then the quantity of happiness between two epochs is represented by the area contained between the zero-line, perpendiculars thereto at

> the points corresponding to the epochs, and the curve traced by the index; or, if the correction suggested in the last paragraph be admitted, another dimension will be required for the representation.

Although "physio-psychology" did not advance to the extent that Edgeworth had hoped during his lifetime, neuroimaging is beginning to unveil the neurocircuitry behind utility today.

In 1938, Samuelson ingeniously developed the theory of revealed preference which enables economic analysis in the absence of direct utility measurement. If choices derive from preferences, then preferences are revealed by choices. This construct has become the traditional practice in economics. Behavioral economics emerged in the early 1980s with some controversy, but has gained momentum since (as evidenced by this volume!).

Neuroeconomics first entered economic discourse in the late 1990s (Glimcher et al., 2009), a convergence of trends in behavioral economics and neuroscience. Behavioral economists valued the tools of neuroscience, particularly functional magnetic resonance imaging (fMRI), to look inside the "black box" that is the brain. Neuroscientists valued the structure of economic models of choice and strategy (Glimcher and Rustichini, 2004).[1]

Neuroeconomic research is not without controversy among economists. Some argue that neuroscience offers no advantage over the neoclassical models (Glimcher and Fehr, 2014; Gul and Pesendorfer, 2008). Spiegler (2008) takes an intermediate position, acknowledging both the weaknesses and the potential of neuroeconomics for economic theory. Camerer et al. (2004) were early promoters of neuroeconomics.[2]

Although the field is still in its infancy, the literature in neuroeconomics is growing. In the comprehensive, definitive volume edited by Glimcher and Fehr (2014), the editors state that nearly 100 institutions worldwide house researchers studying neuroeconomics (p. ix). Recent literature reviews include Fehr and Rangel (2011) and Camerer (2013a).[3]

In our view, neuroeconomics supplements neoclassical theory, as do experimental, behavioral or econometric methods. As intimated by Spiegler (2008, p. 517), "why should we restrict ourselves to the cost-benefit metaphor?" Smith et al. (2014) point out that neuroeconomics is useful when traditional choice data are problematic in some way or unavailable, such as in evaluating a future choice. The well-known bias in individual reports of willingness-to-pay provides an example (Smith et al.). Estimating value from neural data, which precedes stated preference, could be instructive. We take a "practical approach" a la Chetty (2015), viewing neuroeconomics as part of the economist's toolbox to be used when informative to the question at hand.

The next section briefly describes neuroscientific methods. Then we turn to neuroeconomic studies on brand names, advertisements, prices and product attributes and their effects on consumer choice. The last section concludes the chapter.

2.0 Neuroscience Techniques

Neuroscience methods can identify the areas of the brain that are tied to particular preferences and choices. Glimcher and Fehr (2014) and Glimcher (2011) provide details of the physiology and neurology of the brain, and Kable (2011) and Ruff and Huettel (2014) provide overviews of neuroeconomic methods and examples.

How is a neuroscience study conducted? As an example, Fehr and Rangel (2011, pp. 6-7) lay out a three-step process for an experiment designed to test if the brain region encodes or is associated with decision values, i.e., values for each option computed from the start to the end of the decision process:

> First, some form of *behavioral data is used to estimate the value* that the brain assigned to the signal of interest. These behavioral data are sometimes obtained in a separate task: for example, in the case of decision values, by asking subjects to provide incentive-compatible bids for each option used in an experiment, or to provide "liking" ratings. ... Second, a measurement of *neural activity is taken during the choice process in particular brain areas*. ... Third, statistical methods are used to test if neural activity during the period of interest is modulated by the signal (or signals) of interest. If *the neural activity is statistically significantly related to the signal of interest*, then this is taken to be evidence consistent with the hypothesis that activity in that neural substrate encodes the signal.
> (emphasis added)

In the first step, valuation, individuals provide estimates of the pleasure, pleasantness or value that they place on various options. Valuation is akin to our notion of utility. The term "behavioral data" refers to traditional psychological or experimental data apart from neuroscience data. Viewing a product, brand name or advertisement are examples of "signals" (or stimuli) in this literature. Techniques for measuring neural activity for step 2 are discussed below. In step 3, statistical tests for significance include t-tests and chi-squared tests on correlations, differences in neural activity, and even regression coefficients.

Some studies take the process one or two steps further, to *prediction* and *policy implications*. Smith et al. (2014) propose a careful, meticulous procedure for using fMRI data to predict individual and group behavior. Studies reported here which make predictions include

Berns and Moore (2012), Falk et al. (2010), Falk et al. (2011), Falk et al. (2012), and Tusche et al. (2010). The three studies by Falk and colleagues also generate policy implications.[4]

Neural activity can be measured in a number of ways. Perhaps the most widely known neuroscience technique, and the most common in the studies surveyed here, is functional magnetic resonance imaging (fMRI). This technique utilizes an MRI scanner to measure blood oxygen-level changes in an individual's brain while undertaking a behavior of interest (Kable, 2011; Ruff and Huettel, 2014). Because local neural activity increases with blood oxygenation and fMRI measures blood oxygen levels, the fMRI signal indicates neural activity (Kable, 2011, p. 67). The fMRI signal is also known as the BOLD (blood oxygenation level dependent) signal.

In addition to fMRI, some studies that are surveyed in this chapter employ electroencephalography (EEG), near infrared imaging (NIR), patterns of gray matter volume (GMV), and observing behavior of lesion patients to investigate brain patterns associated with brand names or other economic influences. EEG measures the electrical activity in various parts of the brain while an individual is undertaking a task such as viewing pictures of products or an advertisement. NIR measures changes in concentrations of hemoglobin in brain regions, which reflects neural activity, in response to pictures of luxury-branded handbags, for example. Changes in GMV in a particular brain region, say in response to a higher price of a wine, indicates changes in regional neural activity. Observing behavior of patients with lesions in particular parts of the brain can help identify the function of the impaired region in healthy individuals.

Alternative methods employed by other neuroeconomists include: positron emission tomography (PET); transcranial magnetic stimulation (TMS) and transcranial direct current stimulation (tDCS) which can stimulate specific regions in the brain to affect choices; animal studies; and drug manipulation (Camerer 2013a; Fehr and Rangel, 2011; Ruff and Huettel, 2014). Skin conductance response, pupil dilation, eye-tracking, facial temperature and muscle movement are among the physiological methods that can measure consumer responses and are relatively inexpensive and easy to implement (Smith et al. 2014; Camerer 2013a).

Neuroscientific measurement techniques each have particular strengths and weaknesses. Ruff and Huettel (2014) and Kable (2011) provide overviews and examples of each neuroscience method, including advantages and disadvantages of each. For example, EEG and fMRI techniques both have the advantage of being noninvasive, EEG provides poor spatial but sharp temporal resolution of brain activity, and fMRI provides poor temporal but sharp spatial resolution (Fehr and Rangel 2011). Ruff and Huettel (2014), Kable (2011) and Camerer (2013a) conclude that alternative methods should be used together to offset the weaknesses of any particular method alone.

One of the most common findings in neuroeconomics is that neuroactivity in the ventromedial prefrontal cortex (vmPFC) at the time of choice is correlated with the measures of value from the behavioral data (Fehr and Rangel 2011).[5] As mentioned above, measures of value from behavioral data could be likings or pleasantness ratings for products or brands. For instance, if an individual prefers product X over product Y, activation of the vmPFC is expected to be higher for X than for Y. Chib et al. (2009) study individual purchasing decisions for a variety of goods (candy/chips, money, bookstore trinkets) and find activation in the vmPFC for all three types of products. Because they observe the same brain responses for such different goods, the authors conclude that there is a “common currency” of valuation or pleasure in the vmPFC. What we regard as utility appears to be measurable by brain activity in the vmPFC.

A number of other significant correspondences between activity in brain regions to economic behaviors and decisions have been uncovered, many of which are discussed in sections to follow. There may not be a one-to-one correspondence between a particular task and a specific brain location, however. Many brain areas may be involved in a specific function, and a particular brain region may be activated during many different tasks. Camerer et al. (2004, p. 561) explain the concept of brain circuitry:

> Most complex behaviors of interest to economics require collaboration among more specialized modules and functions. So the brain is like a large company—branch offices specialize in different functions, but also communicate to one another, and communicate more feverishly when an important decision is being made. Attention in neuroeconomics is therefore focused not just on specific regions, but also on finding ‘‘circuits’’ or collaborative systems of specialized regions which create choice and judgment.

In this chapter, we refer to neural activity, neurocircuit activity and brain region activity interchangeably; more specific information appears in Glimcher and Fehr (2014) and Glimcher (2011). [6]

We turn now to the neuroeconomic literature on brand names, advertisements, prices and selected product attributes.[7] Because many of the experiments take place in the confined environment of an MRI scanner, actual product consumption (i.e., “experienced consumption”) has focused on the beverages, such as colas, wine, beer, coffee, and milkshakes; artwork viewed on a screen; and music. In some experiments, valuation of products is measured as individuals see pictures on a screen (handbags, luxury products). In addition TV advertisements can be shown directly and brain activity examined (sunscreen, anti-smoking ads, and Sony ads).

3.0 Neuroeconomic Studies

Advertising can affect consumer choice directly through media advertisements and by establishing or enforcing brand names. In this section, studies on brand names are first reviewed, followed by studies on advertisements. Then, related research on the influence of price and product attribute signals on consumer valuation and choice are discussed.

3.1 Brand Names

Firms can use branding to exploit a number of behavioral weaknesses of consumers. For example, once established, a brand can serve as a reference point for future purchases, and consumers may avoid brand switching due to loss aversion (Hardie et al., 1993).[8] Indeed, Fox and Poldrak (2014, p. 540) state "Loss aversion when making tradeoffs may partially explain the ubiquity of brand loyalty in the marketplace." In addition, in a complex world with a multitude of choices among products, advertising investments in brands may act as a signal of quality.

Brand names can also enforce and manipulate social identity.[9] From the employer's perspective, efficiencies can be gained by a shared employer-employee identity (e.g., Butler, this volume). A trademark or brand name can be associated with quality or honesty, for example, and can facilitate shared identity. On the consumer side, advertisers may attempt to tie social identities to their brands. Akerlof and Kranton (2000, 2010) claim that advertising manipulates identities and can create new ideals, and Bènabou and Tirole (2011, p. 838) state that advertising "plays up people's desires to achieve or affirm certain identities." For instance, a consumer might identify with the image of Budweiser and another consumer might identify with the image of a local craft beer. If reinforced by social group membership, brand image becomes an even more powerful influence on consumer choice.

Behavioral brand studies show that consumer valuation of homogeneous products is enhanced by perceived brand associations. Perhaps the most well known is Allison and Uhl (1964) who found that beer drinkers ranked their favorite beer more highly than other beers when bottles were labeled, but not when bottles were unlabeled. Another example is Nevid (1981) who found that consumers preferred Perrier to seltzer when Perrier is identified by the label, but not when the brand is unknown.

Neuroeconomic studies show that brand names can affect brain activity.[10] The vmPFC, as a center of valuation as discussed above, plays an important role in many of the brand studies. However results differ across studies, in part, because of the various mental tasks involved in decision-making. Plassmann et al. (2012) review the neuroscience research on the influence of brands on decisions. They adapt the general framework for value-based decision-making of Rangel et al. (2008) to the case of brand applications. Plassmann et al. (2012, p. 20) map out the brain regions that appear to be activated during each stage of the process, reproduced in Figure 1. Steps in the process are listed below with the implicated brain areas as indicated in Figure 1 noted in brackets.

1. Representation and attention, which entails consumer identification of the choice set, including brand identification [visual cortex]
2. Predicted values of the choices (brands) [vmPFC/mOFC, dlPFC, VS&NAcc]
3. Experienced value of consumption [vmPFC/mOFC, lOFC]
4. a. Remembered value [hippocampus, dlPFC]
   b. Learning (upgrading of brand associations) [VS & NAcc]

which *feed back to predicted and experienced values*. [11]

As indicated in the figure, the abbreviations in brackets are: dlPFC = dorsolateral prefrontal cortex;

lOFC = lateral orbitofrontal cortex; mOFC = medial orbitofrontal cortex; NAcc = nucleus accumbens; vmPFC = ventromedial prefrontal cortex; and VS = ventral striatum.

< Figure 1 about here >

The studies that follow refer to these (and at times other) brain locations that appear to relate to particular aspects of decision-making in the presence of brand information. We start with neuroeconomic brand research on the beverage industry (soft drinks, beer, coffee), followed by studies on magazine brands, music sales and luxury brands (handbags and an amalgam of luxury products).

In a widely recognized study, McClure et al. (2004) conduct a set of behavioral and fMRI experiments regarding the influence of brand knowledge on preferences for Coke or Pepsi. The chemical composition of both products is nearly identical, yet some people have a strong preference for one or the other. Prior to the behavioral experiment, subjects stated their preference for Coke ("Coke drinkers"), Pepsi, or no preference. When comparing unlabeled cups of Coke and Pepsi, Coke drinkers did not chose Coke more frequently; however, when comparing two cups of Coke, one labeled and one unlabeled, Coke drinkers preferred the cup marked Coke. The fMRI experiments were consistent with the behavioral results. For Coke drinkers, fMRI scans revealed that drinking Coke stimulated greater activity in the "reward center" of the brain (specifically the ventromedial prefrontal cortex, vmPFC).[12] Brand identification generated additional significant brain activity in a number of structures including those linked to memory and affective responses (dlPFC and hippocampus). Interestingly, the results did not hold for Pepsi drinkers: knowing the brand did not significantly change brain activity.

Koenigs and Tranel (2008) also employ Coke and Pepsi taste tests but with three groups of participants: those with lesions to the vmPFC and defects to emotional processing; those with brain lesions not affecting the vmPFC; and those with no brain lesions. In blind taste tests with unmarked cups, all three groups preferred Pepsi over Coke. When one cup stood by a Coke can and the other cup was not identified, the group with vmPFC lesions continued to prefer Pepsi, but the other two groups changed to Coke, consistent with the McClure study. Defects in emotional processing for the vmPFC-lesion participants may actually insulate them from social pressure or emotional associations with advertising and brand images. Biases in valuation by normal and non-vmPFC lesion participants due to brand images are averted. In an earlier study using fMRI, Paulus and Frank (2003) emphasize that activity in the vmPFC significantly relates to soft drink brand choice. In their study, participants did not actually consume the soft drinks, but expressed a preference between two brands on a screen. Brain activity during these preference judgements was contrasted with brain activity during a "visual discrimination" trial in which subjects chose which of two soft drinks pictured was contained in a bottle (as opposed to a glass). Although other areas of the brain were implicated by the preference judgements (the posterior parietal cortex, the anterior cingulate and the left anterior insula), the authors stressed the importance of the vmPFC.

Deppe et al. (2004) assess the brain activity of a group of economics students in selecting among brand choices of coffee for women and beer for men. The authors maintain that these products (apart from the brand name) are fairly homogeneous, particularly beer as the study took place in Germany where the Reinheitsgebot – German purity law – limits the ingredients allowed in the brewing process. While in the fMRI scanner, participants expressed their preferences between alternative brand pairs shown on a screen. Those participants choosing between their favorite brand and other brands had significantly greater neural activity in the vmPFC than those choosing between two non-favorite brands, and lesser neural activity in areas involved in working memory and the visual cortex.

Turning to magazine brands, Deppe et al. (2005) analyze the impact of magazine brand credibility on the judgement of individuals regarding whether headlines are true or false. As the experiment took place in Germany, brand information (logos, headline style) from four actual German magazines were presented to the participants in conjunction with fictitious headlines related to current events and designed to indicate variable plausibility. A separate group evaluated the credibility of the headlines. The authors characterize the logo-headline at the time of judgment as a type of "framing" and brain activity during participant evaluation of headlines as an indication of the framing effect. Two weeks after scanning, participants rated the credibility of the four magazines. The fMRI evidence showed that the more credible the magazine brand, the greater the activity in the vmPFC and that individual differences in vmPFC activity indicate susceptibility to framing effects induced by brand information. Another explanation for these results is that if consumers are uncertain about the quality of a news item, they will look to the credibility of the source as an indicator of the probability that a news item contained in the represented magazine is credible. In other words, the information is useful for making an informed choice.

A similar study examined the impact of magazine brand information on the aesthetic attractiveness of advertisements by participants (Deppe et al., 2007). The authors focused on the anterior cingulate cortex (ACC) which they describe as a "central node in a neural network responsible for the integration of information about positive or negative reinforcements. This node thus relates actions to consequences, and is central to conflict monitoring and cognitive control” (Deppe et al., 2007, p. 1119). If individuals face conflict when viewing an attractive ad along with non-credible magazine information, or see an unattractive ad along with credible magazine information, the ACC may respond. The fMRI results showed that neural activity in the ACC positively relates to the extent of bias that consumers exhibit in evaluating ad attractiveness attributable to the magazine brand. As with the vmPFC findings in the Deppe et al. (2005) study, ACC response differences across individuals predict varying impacts of brand on evaluations.

A study by Berns and Moore (2012) predicts music sales at large based on brain patterns of individuals. Music is an interesting product in that it can be consumed directly in the MRI scanner. It is also interesting because the brand is the artist or the band. In this experiment, adolescents listened to songs by unknown musicians that had been downloaded from MySpace.com. At this juncture, the “product” might be considered unbranded. As artists become popular, they may be acquiring a “brand name”. While each participant listened to an unknown song, brain activity was recorded. Following each song, participants reported likability ratings. Over a three year period, aggregate sales of each song were documented. Average likability ratings reported by the participants did not correlate with future sales. However, activation within the NAcc when the individuals were listening to the music bore a positive and significant relationship to later sales. The combined influence of OFC (orbitofrontal cortex) and NAcc/VS (nucleus accumbens/ventral striatum) did not significantly predict “hits” in a logit model but did significantly predict “non-hits”. The authors point out that the OFC and NAcc are reward-related regions and generally predictive of purchasing decisions.

Lin et al. (2010) consider brand loyalty, luxury products, and attractive products. The authors used Near-Infrared Ray (NIR) imaging to assess changes in concentrations of hemoglobin in the MFC, indicating neural activity. While wearing an NIR probe around their forehead, participants evaluated 120 alternative handbags (including brands Burberry, Chanel, Christian Dior, Coach, Gucci, Hermes, Louis Vuitton, Marc Jacobs, Prada, and YSL). After the NIR imaging was completed, participants self-identified as brand loyal or not for each of the brands. Fashion experts had previously classified the handbags as luxury or generic, and attractive or unattractive. Participants were unaware of the expert appraisals. Lin et al. find that product attractiveness (as evaluated by the fashion experts) correlates with activity in the MFC, while the luxury feature of products did not significantly affect MFC activity. At the same time, brand loyalists were more sensitive to differences between luxury and generic products, and between attractive and unattractive products, compared to those with no brand loyalty. In another study of luxury brands, Pozharliev et al. (2015) examine the influence of the presence of another person on neural responses to luxury products (chocolates, beverages, shoes, and lingerie).[13] EEG patterns for Dutch female students were observed as they viewed pictures of luxury branded and basic products on a computer, alone and with another student present undergoing the same experiment. The authors focus on activity in the visual cortex, which is associated with viewing emotional rather than neutral pictures (Pozharliev et al., p. 548). The authors hold that luxury brands have high emotional value relative to basic products, although they may evoke positive or negative emotions. EEG results show greater neural activity for the luxury than the basic products when another person is nearby.

3.2 Advertisements

The traditional advertising literature entertained a number of views on the role of advertising in demand and welfare (Tremblay and Tremblay, 2012, Ch. 15). Informative advertising was viewed as a positive influence on welfare while persuasive advertising, which generates a demand shift without any real differences in the product, was viewed with skepticism. Advertising can also be used to create product images. In this case, advertising generates a demand shift but carries utility gains for the consumer. The welfare implications of image-creating advertising is controversial. This age-old debate may not be solved by neuroscience, but perhaps it can bring some information to the table.

Some of the neuroeconomic brand studies in the previous section indicate that people are receiving pleasure from brand associations, as shown by activity in the vmPFC. In this section, we explore two studies that attempt to use brain responses to advertisements to separate informational from emotional content (one with a set of newspaper and magazine ads, the other with TV ads for SONY Bravia televisions). Similar to the music study by Berns and Moore (2012), three additional studies, one on advertisements on sunscreen use and two on antismoking advertisements, use brain activity to predict later behavior. In fact the third of these actually uses brain activity from a small group of individuals to predict *population* responses to alternative TV advertising campaigns.

Starting with the informative-emotional aspects of advertising, Cook et al. (2011) compare brain activity when participants viewed logical, persuasive (LP) advertising with non-rational influence (NI) advertising. The term "persuasive" in this study does not coincide with the traditional meaning in industrial organization stated above, but refers to "logical, factual information that is rationally persuasive" (p. 147), more akin to informative advertising. Non-rational influence occurs when advertising modifies behavior without being perceived consciously or processed rationally. Cook et al. state that the NI-LP dichotomy aligns with the dual systems approach of Kahneman (2003): NI corresponds to System 1 (which yields quick, easy, automatic choices and can be subject to emotions), and LP corresponds to System 2 (which involves deliberate and effortful thought). [14]

The authors use EEG (electroencephalography) to assess electrical activity in brain regions for participants while viewing images with LP content, NI content, and at rest. Images were drawn from actual newspaper and magazine advertisements of different products. The LP ads contained factual information and were tied directly to the product. One example shows a toothbrush with "details about how to build a better toothbrush" (Cook et al., p. 150). The NI ads were provocative and devoid of product information, e.g., a picture of water pooling on glass in the shape of a dead body or sexually suggestive pictures. Using t-tests on differences in electrical current density, significant differences in brain activity for NI and LP advertisements occurred. LP ads generated significantly greater activity than NI ads in the vmPFC, ACC, and hippocampus (HIP) which have been introduced above, as well as the right-sided amygdala (AMY).[15] It is interesting that no region produced more electrical activity for the NI ads than for theLP ads. Recall that the vmPFC is involved in valuation and predicting value of alternative choices. It inhibits responses to stimuli leading the authors to speculate that vmPFC activity might lead to "patterns of less restrained behaviors in connection with products depicted in the NI advertisements" (p. 155). The ACC region is implicated in emotional processing but also in "selecting which stimulus merits a response in the face of competing streams of information … The higher ACC currents we found during LP stimuli could be interpreted as being consistent with greater processing needs for the factual information presented in LP ads." The AMY plays a role in "emotional processing and vigilance" and the right AMY was previously linked to affective information processing of image-related material. As previously mentioned, the HIP affects memory formation. Results did not differ significantly by gender. By way of a general conclusion, not all ads are processed the same by the brain – informational ads generate more brain activity than emotional ads.

In another examination of emotional and informational advertising content, Ohme et al. (2010) observe prefrontal cortex activity using EEG while people watched TV advertisements for Sony Bravia TVs. Based on previous studies, left hemisphere activation is involved in potentially desirable outcomes and approach behavior, while right hemisphere activity is involved with aversive outcomes and withdrawal tendencies. Of interest is what advertisements facilitate approach behavior, and to that end, the authors measure the difference between left hemispheric and right hemispheric frontal cortex activation. Ohme et al. compare brain activity while participants viewed three different TV advertisements for Sony Bravia televisions, known as the "Balls" (2005), "Paint" (2006), and "Play-Doh" (2007) ads.[16] Secondly, the authors compare brain activity at different phases of the ads. Each ad follows the same pattern. Advertising experts identified the first part of the ads as emotional: the "Balls" ad shows a colorful ball bouncing down a street in San Francisco joined by other balls, 250,000 in total; the "Paint" ad features 70,000 liters of colorful paint fountains and fireworks culminating in a tower covered with paint in Glasgow; the "Play-Doh" ad depicts 200 Play-Doh bunnies on the streets of Manhattan, coming together to form a giant rabbit. Impactful music accompanies the striking visuals.

The second part of the ads is labeled "informational" and consists of three subscenes showing types of product information: a picture with the word "color", the picture and name of product (Sony Bravia TV) and then the brand name (Sony). We might question whether or not the brand name is informational or at least in part emotional, but brand is tested separately as well as a part of the informational set. Further, in this framework, emotional and informational segments would have the same effects if they generate approach relative to withdrawal behavior (i.e., greater electrical activity in the left than the right hemisphere of the frontal cortex).

The "Balls" ad stands out (Ohme et al.). When participants viewed the "Balls" ad, significantly greater relative left prefrontal activation occurred, whereas that was not the case with the other two ads. Further, the emotional segment and the informational segments both exhibited significant asymmetric frontal cortex activity for "Balls". The brand subscene alone did not show significant differences, however, except for a version of the "Balls" ad that had animation just prior to the brand segment. Of interest is that all three ads were created by the same ad agency and were highly acclaimed. In an *Advertising Age* piece, Parish (2007) states that neither Paint nor Play-Doh "finds the spontaneity that gave 'Balls' its simple charm and feeling of adolescent joy", consistent with the neural activity of the participants in the Ohme et al. study in 2010.

Although both informational and emotional content in the Balls ad generated favorable brain patterns, Ohme et al. note that the emotional part of the Balls ad may be a prime for the informational part. That is, the relative approach behavior established in the emotional part might carry through the informational part of the ad. If this is the case, the Balls result would not tell us much about informational advertising. The next papers by Falk and colleagues focus on informational advertising and the use of fMRI data to predict behavioral responses of participants to health information.

In Falk et al. (2010), participants viewed slides of informational ads regarding the benefits of sunscreen in a scanner.[17] Activity in the medial prefrontal cortex (MPFC, which has been associated with self-referential processing and overlaps with the vmPFC discussed earlier) was used as a regressor in an equation of change in sunscreen use from one week before to one week after the scan. MPFC activity significantly predicted change in sunscreen use, even controlling for changes in the individual's intention to use sunscreen and attitude toward sunscreen. That is, MPFC activity precedes behavior change and could provide some predictive power. Changes in sunscreen use, intentions and attitudes were self-reported, and might be subject to biases, but brain activity is registered prior to self-reports of changes in use and attitudes. In addition to the MPFC, the fMRI revealed "correlations between behavior change and neural activity in regions involved in taking the perspective of others ... in memory encoding, attention, visual imagery, motor execution and imitation, and affective experience" (p. 8424).[18] Taken together, the authors interpret these findings as consistent with theories indicating that "behavior change can result from encoding information about social norms, incorporating those norms into one's own self-concept, and planning to execute the relevant behaviors" (p. 8424). This would tie into the economics of identity literature in which social norms affect identity and behavior (e.g., Butler, this volume).

In another health application, Falk et al. (2011) use neural activity in the ventral subregion of the MPFC to predict the effectiveness of anti-smoking advertisements at curtailing smoking. The participants, who were heavy smokers intending to quit, viewed 16 professionally developed anti-smoking advertisements in an MRI scanner. Ads were from public health agencies and foundations and included testimonials, humorous ads, and ads focusing on second-hand smoke and the difficulty of quitting. Exhaled carbon monoxide (CO), indicative of recent smoking, was measured prior to scanning and 1 month following scanning. The authors regress change in exhaled CO on vmPFC activity while ads were viewed as well as self-reported measures of ad effectiveness.[19] Greater MPFC activity significantly increased the reduction in exhaled CO following anti-smoking ad exposure, in both a simple regression ($R^2 = 0.20$) and multiple regression with the self-reported variables ($R^2 = 0.35$). Hence, Falk et al. (2011) show that neural activity helps to predict changes in smoking from anti-smoking ads for individuals.

Breaking new ground, Falk et al. (2012) predict behavior at the population level based on the effects of alternative anti-smoking TV ads with individual measures of brain activity from the Falk et al. (2011) study. MPFC activity for participants for ads from three actual campaigns (denoted A, B, and C), all closing with the National Cancer Institute's Smoking Quitline phone number, indicated that ads from campaign C would be most effective in generating calls to the Quitline and deterring smoking. Participants and experts reported that they expected that campaign B would be most effective. The three ad campaigns were aired in three different population centers, and call volume to the Quitline was recorded and compared to call volume prior to the ad campaigns. Remarkably, the increase in call volume was the greatest for campaign C.

3.3 Prices, Product Attributes and Valuation

Prices and product attributes share particular features with brand names and advertising. First, utility can be influenced by price and product attributes. Second, uncertainty about product quality can lead consumers to use advertising, brand names, prices and product attributes to signal high (or low) quality goods. In this section, we consider a behavioral beer price study and fMRI wine price studies. We also consider particular product characteristics: the perceived expertise of the producer of artwork, and organic/regular and light/regular attributes of milkshakes. The final work pulls together a number of experiments and identifies personality characteristics linked to brain regions which can be used to predict consumer choice.

Consumers might view price as a reflection of quality (Fluet and Garella, 2002). In a behavioral study by McConnell (1968), participants chose among three beers that were priced differently. Even though the beers were all the same brand of beer, consumers valued the highest price beer more than the lowest price beer. Only 9 of 60 people rated the beers at the same quality level. One participant stated that he never could finish a bottle of one of the beers and that he had to pour it down the sink.

Would neural circuitry respond to price differences for homogeneous products? Plassmann et al. (2008) conduct a behavioral and fMRI study on the effect of perceived wine prices on the reported pleasantness of wines. Five different Cabernet Sauvignons were given to subjects while they were in a scanner, each identified by a different price. In reality, there were only three unique wines; two wines were labeled with both a high and a low price. Participants indicated taste pleasantness ratings of the wines. The pleasantness ratings were positively and significantly correlated with the stated wine prices overall. Further, significant differences in mean liking scores for high- and low-priced versions occurred for both duplicated wines.[20] The fMRI scans revealed that higher prices activated the medial orbital cortex (mOFC) as expected by the authors since mOFC is "widely thought to encode for experienced pleasantness" (Plassmann et al., p. 1050). Like brands, price may also represent social status as well as product quality.

Kirk et al. (2009) consider aesthetic evaluations of artwork in relation to the perceived source of the artwork. Would it matter to a consumer if a painting came from a prestigious gallery or if it were computer-generated by the experimenter? To find out, subjects were scanned while viewing images of paintings marked either "museum" or "computer", and they rated the paintings on aesthetic appeal. All of the images were of actual abstract paintings, i.e., none were computer generated.[21] Paintings with the museum label were deemed significantly more appealing than those with the computer label by the participants, even though the visual appeal of the paintings was controlled.

Building on the work regarding wine and art expertise, Plassmann and Weber (2015) conduct a novel and thorough investigation of individual differences in personality traits linked to brain responses to signals or cues, such as price or product characteristics.[22] By way of overview, the authors first identify brain activity in "regions of interest" (ROIs) linked to changes in experienced utility due to price or another cue. Next, from extensive sources and methods, they find personality traits associated with the ROIs. Finally, the authors use individual scores from the psychological assessments linked to the identified personality traits as explanatory variables in a regression with change in experienced utility as the dependent variable.

In the first stage, there are some interesting innovations. Brain activity is measured using gray matter volume (GMV) in three studies: two wine-price experiments and one milkshake-labeling experiment. The authors state that "regional gray matter volume, as measured by MRI, corresponds to the regional volume and wiring of nerve cell layers in the brain". Increases in GMV in a brain location indicate greater neural activity. The first wine study analyzed the data from Plassmann et al. (2008) but used GMV instead of fMRI results. The second wine study modified the Plassmann et al. (2008) experiment: wines were all of the same price class but were assigned three different prices, and participants might receive the wines for free or might have to pay for the wine. Results from Plassmann et al. (2008) held for the price condition but not for the free/pay condition. The third experiment addressed the effect of "organic" or "light" attributes on the valuation of consuming a milkshake. One group of participants believed that they were consuming milkshakes that were either "organic" or "regular" although the milkshakes were identical. Another group believed that they were consuming milkshakes that were either "light" or "regular" while the shakes were likewise identical. In both behavioral and fMRI analyses, the organic label significantly raised participant valuations of the milkshakes while the light label significantly reduced valuations.

Plassmann and Weber (2015) pooled gray matter volume results from participants of all three experiments for the three regions of interest that are consistent with the literature as well as their full brain scan results: dmPFC, striatum, and posterior insula. Of interest is that these regions stood out in the wine and milkshake experiments even though they are different products and the cues and conditions differ (price, attributes). At this point their goal is to see if GMV changes in these regions affect changes in experienced utility from the high expectation state (e.g., high prices for wine) minus the experienced utility from the low expectation state (e.g., low prices). Experienced utility is measured by the behavioral data, e.g., participant responses to how much they liked a particular wine (1 = not at all, ..., 6 = very much). Using regression analysis they find that GMV in the dmPFC, striatum, and posterior insula significantly affect the difference in experienced utility from the high to low expectation state at 5% or better, whether or not gender and age are included.[23] GMV in the dmPFC and striatum have a positive effect while GMV in the posterior insula has a negative effect.

In stage 2, the authors identify personality traits associated with the three ROIs, informed by a multitude of sources and an extensive database and then find psychological instruments that measure these traits. Plassmann and Weber (2015) conclude that individual differences in changes in experienced utility from (and susceptibility to) cues or signals are linked to "reward processing as signified by differences in gray matter volume in the striatum, somatosensory awareness as signified by differences in gray matter volume in the posterior insula, and cognitive appraisal of emotional experiences as signified by differences in gray matter volume in dmPFC." Somatosensory awareness means awareness of sensory processing of bodily states. Individuals who are perceptive of the effects of sensory stimuli would be less likely to be influenced by price or other cues. Taking this information one step further, the authors find psychological instruments related to reward processing (reward-seeking subscale of the behavioral activation system - BAS),[24] somatosensory awareness (private body consciousness scale - PBC),[25] and cognitive appraisal of emotional experiences (need for cognition scale).[26] Using three simple regressions (one for each of these scales) with three wine-price behavioral data sets, the authors find that each scale significantly determines differences in experienced utility for high price compared to low price wines.

In the final stage, Plassmann and Weber (2015) test to see if the three psychological scales predict experienced utility differences in a different realm, valuation of artwork as in the gallery/computer experiment above. They used the same artwork that was used in the fMRI study above by Kirk et al. (2009). Plassmann and Weber surveyed an online sample of participants with regard to their evaluation of the artwork and answers to questions on the personality scales. The authors confirmed the results of Kirk et al. that individuals rated the artwork more highly when they believed that the art was created by an artist from a gallery than when it was generated by the experimenter on a computer. Using a multiple regression with the dependent variable equal to the difference in experienced utility for "gallery" and "computer" art, Plassmann and Weber find that the coefficients on all three scales, BAS, PBC, and need-for-cognition, are significant. The authors conclude that consumers most susceptible to the influence of price, labeling or art expertise information tend to score high on reward-seeking and need for cognition and tend to score low on somatosensory awareness. Plassmann and Weber take a new path in using a new neuroscience method (GMV) and in honing in on response differences across individuals.

4.0 Conclusion

Neuroeconomics can provide data when choice data are unavailable or impractical. The studies reviewed here illustrate how different neuroscientific methods can be used to identify valuation of products, what we might view as utility. Brand names, advertisements, prices and product characteristics activate specific brain regions, even for homogeneous products. In some cases, brain activity can actually predict consumer choice better than consumers' stated preferences, can predict choices at the population level, and can give rise to policy implications.

This chapter contains a sampling of studies relevant to selected topics in behavioral industrial organization. Neuroeconomics research contributes to the knowledge base for industrial organization economists in other areas as well, such as game theory and bargaining, cognitive dissonance, endowment effects, loss aversion, risk and uncertainty, and intertemporal choice and self-control.[27]

Neuroeconomic research began primarily by linking particular brain regions to economic decision-making. Predictive studies are just beginning and policy implications are rare. As technology and methods of analysis continue to advance, it is expected that research using neural activity to predict economic behavior and generate policy implications will bring new insights to industrial organization and to economics as a whole.

Endnotes

[1] Not all neuroscientists accept neuroeconomics, however (Glimcher and Fehr, 2014, xxiii).

[2] See also Caplin and Schotter (2008, Part II).

[3] Camerer (2013b) also contains general information about neuroeconomics before conducting a book review.

[4] An intriguing discovery of coactivity in related neurocircuits for working memory and impatience indicates that memory training may improve patience (Camerer, 2013a; Peters and Büchel, 2010).

[5] See Figure 1 in Section 3.1 below to see the location of the vmPFC in the brain.

[6] Camerer (2013a, p. 427) defines a neural circuit as an "anatomically distinct brain area that is functionally connected and mutually activated during behavior."

[7] Other neuroeconomic studies relevant to industrial organization include: Krajbich et al. (2014) and Sanfey et al. (2003) for bargaining and game theory; Glimcher and Fehr (2014) for decoy effects; Izuma et al. (2015), Kitayama et al. (2013), Jarcho et al. (2011) and Izuma et al. (2010) for cognitive dissonance; Ericson and Fuster (2014), Tong et al. (2016), and Knutson et al. (2008) for the endowment effect; and Halko et al. (2015) for loss aversion. Additionally see Glimcher and Fehr (2014) and Camerer (2013a) for studies on bargaining and game theory, loss aversion, framing, risk and uncertainty, and intertemporal choice and self-control.

[8] Loss aversion arises when people place greater weight on losses than on equivalent gains.

[9] Huettel and Kranton (2012) call for research in "identity neuroeconomics".

[10] Perhaps these should be viewed as "reduced form" studies including identity effects.

[11] Platt and Plassmann (2014) lay out a simpler process for value-based decision-making in the general case: predicted valuation of options before choice; choice; experienced valuation or

pleasure in experiencing the chosen outcome; and learning. They also review studies on location of brain activity in each stage.

[12] Gustatory cortical regions of the brain (insular cortex) exhibited significant activity when Coke or Pepsi was ingested but did not change with experimental conditions.

[13] Some of the luxury-basic brand pairs include: Ferrero Rocher-Duo Penotti chocolate; Godiva-Verkade chocolate; Pepsi cola-First Choice Cola; Starbucks coffe-Deli coffe; Gucci-Van Haren shoes; Christian Dior-Schoenen Reus shoes; and Victoria's Secret-Hema lingerie. Basic brands may be unknown outside the Netherlands. See online supplement for complete list of product pairs (http://dx.doi.org/10.1509/jmr.13.0560).

[14] Using fMRI data on men who either viewed and evaluated cars (high attention group) or engaged in a task with cars in the background (low attention group), Tusche et al. (2010) find that brain activity patterns predict later choice of willingness to buy a car even for the low attention group. They conclude (p. 8031) that "even complex and important economic choices can be prepared automatically, in the absence of explicit deliberation and without attention to products."

[15] The authors refer to the OFC (orbitofrontal cortex) in their discussion rather than the vmPFC, but the OFC and vmPFC are the same anatomical structure (Phillips et al., 2002).

[16]See Parish (2007, http://adage.com/article/pick-of-the-week/sony-bravia-play-doh/120996/) for videos of the ads.

[17] An example showed black print on a white background stating: "UV rays reach you on cloudy and hazy days, as well as bright and sunny days. UV rays will also reflect off any surface like water, cement, sand, and snow. Therefore, it is always important to wear sunscreen. Some people think that it is only important to wear sunscreen on days when they go to the beach, but to

maintain healthy, happy skin long into old age, it is important to apply sunscreen on any day when you will be outside. Wearing sunscreen consistently is the best way to promote attractive and healthy skin!" The slide indicated "American Academy of Dermatology" at the top left and displayed the symbol of the American Academy of Dermatology in the lower right corner (Falk et al. 2010, supplement).

[18] Specifically (p. 8423) "activity in regions associated with considering the mental states of others (posterior superior temporal sulcus, pSTS; temporal parietal junction, TPJ; temporal pole), memory encoding (hippocampus), attention (supplementary motor cortex, inferior parietal cortex), visual imagery (occipital cortex), motor control and imitation (motor cortex) and affective experience (insula)."

[19] That is, self-reported variables were based on ratings of the following statements : "This ad makes me feel that I can quit"; "This ad makes me more determined to quit"; and "I can relate to this ad".

[20] In a behavioral study, Wansink et al. (2007) find that the perceived location of origin of a wine (California or North Dakota) affects the demand for the complementary good, food. In a restaurant setting, people ate more food when they believed the wine was from California than when it was from North Dakota.

[21] An independent group rated the paintings on aesthetic appeal. Ratings were balanced between gallery and computer labeled paintings.

[22] In the consumer psychology literature, an "expectancy" is a prediction or belief about future outcomes, which can affect consumer experiences and choices. (For example, see Plassmann and Weber, 2015 and Plassmann and Wager, 2013). Brand names and prices are examples of expectancies, more specifically marketing-based expectancies. The literature discussed in the

section above indicates that expectancies do influence outcomes. Marketing expectancy effects are also known as marketing placebo effects (Plassmann and Weber, 2015). One could also say that signals of quality or expectancy cues are types of “context” as in Kirk et al. (2009).

[23] $R^2 = 0.315$ when gender and age are included. Coefficient estimates on gender and age were not significant. $R^2 = 0.298$ when gender and age are excluded from the regression.

[24] According to Plassmann and Weber (2015), the BAS scale measures “how responsive people are to rewards”. The five-point scale “has items such as ‘When I get something I want, I feel excited and energized’.”

[25] The PBC subscale measures “how attentive (conscious) a person is to his or her internal body signals. The scale has items such as ‘I’m aware of changes in my body temperature’” (Plassmann and Weber, 2015).

[26] Cacioppo et al. (1984), who created the need for cognition scale, state that “Need for cognition refers to an individual’s tendency to engage in and enjoy effortful cognitive endeavors.” Examples of questions on the need for cognition assessment relate to preferences for thinking abstractly and finding new solutions to problems or puzzles. According to Cohen et al. (1955, p. 292) , the need for cognition is “a need to structure relevant situations in meaningful, integrated ways” and “a need to understand and make reasonable the experiential world” (Plassmann and Weber, 2015).

[27] See note 7 for references.

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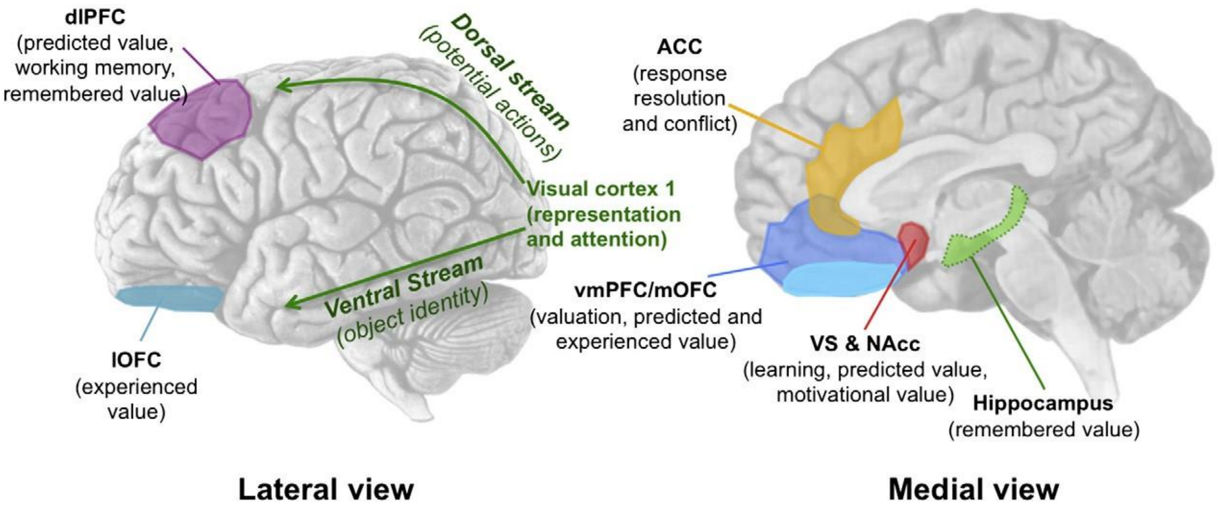
Figure 1 – Brain Areas Linked to Brand Decision-Making



Source: Plassmann et al. (2012) Fig. 3. Overview of prominent brain areas involved in brand decisions. Abbreviations used: ACC = anterior cingulate cortex; dlPFC = dorsolateral prefrontal cortex; lOFC = lateral orbitofrontal cortex; mOFC = medial orbitofrontal cortex; NAcc = nucleus accumbens; vmPFC = ventromedial prefrontal cortex; VS = ventral striatum.