



UNIVERSITY OF PADOVA

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Final dissertation

**A Review of Eye-Tracking and fMRI
Measurements in the Context of
Neuromarketing and Consumer
Purchasing Decisions in E-Commerce**

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CHAPTER 1

INTRODUCTION, AND THE IMPORTANCE OF VISUALS IN ONLINE SHOPPING

E-Commerce has recently experienced a staggering growth, influenced by the COVID-19 pandemic, with sales worldwide reaching more than US\$5.7 billion in 2021 (Statista, 2022). But while the ease of use of shopping and the quantity of items in the virtual shopping space has increased, so has the need for the products to stand out from their competitors (Wind & Mahajan, 2002). “[...] Retailers must develop effective online visual merchandising strategies to create an e-shopping environment and deliver an engaging and pleasant customer experience” (Jai, et al., 2021). Companies must also differentiate their products from their competitors to grow their market share (Banbury & Mitchell, 1995). But the sheer quantity of competing products in any given market makes it exponentially more difficult to stand out. This is not helped by the fact that existing in an online space takes away the sensations other than sight and sound that we use in a physical shopping space, in order to decide on products. Without being able to personally examine the product that they are interested in, consumers feel more uncertain about their purchasing decisions (Childers et al. 2001). Thus, visual attention is a bigger part of the picture, and so images and videos play a more relevant part in the purchasing decision of a product than text does (Kim & Lennon, 2008). For instance, a study on the preference for certain types of sneakers used Eye-Tracking to focus on the AOI (Areas of Interest) of sneakers. They found that cow leather material on the sneakers were more visually appealing to the participants than the other types (See Figure 1A and 1B; Chen & Song 2022).

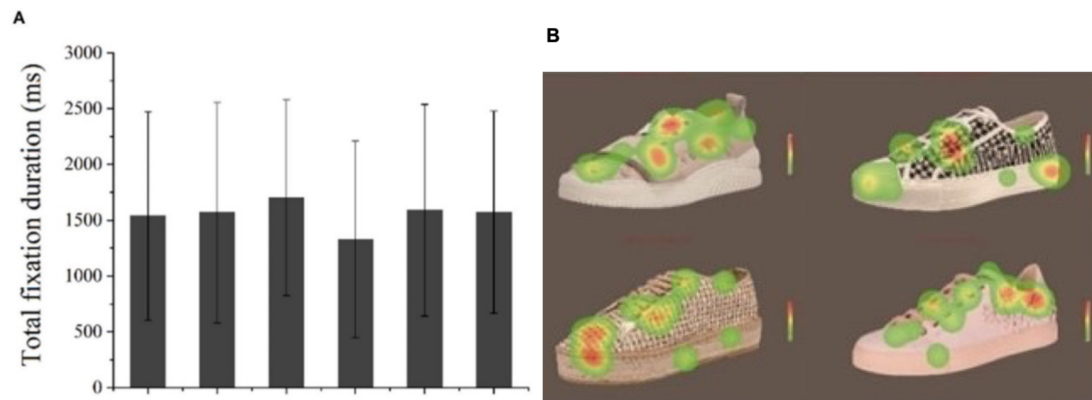


Figure 1: (A) The effect of vamp materials on eye movements, and (B) display of the heat maps of four sneakers from a participant. Source: adapted from Chen & Song (2022).

1.1 Sensory-Enabling Technologies on the Internet

There have been investigations into “Sensory-Enabling Technologies” (SET’s) that could enable new sensory experiences on the internet. A review by Petit, Velasco & Spence (2019) has comprehensive tables that summarize and cite research into newly emerging SET’s, such as “Augmented Reality” (AR), smell inputs, digital taste interfaces and tactile actuators (See Table 1). The benefit of these SET’s, when properly implemented, would be that they could help to inform the consumer about sensory properties of a physical product, such as the smell, texture and taste, all characteristics that are not accessible through traditional online environments.

	Common interfaces		New sensory-enabling technologies	
	Means/cues	Concepts	Means/cues	Concepts
Sight	Screen: Font, icon, picture, videos (color depth, size, position, dynamic).	Mental imagery (Cian et al. 2014; Eelen et al. 2013; Elder and Krishna 2012; Petit et al. 2016) sensory congruency (Sunaga et al. 2016; Velasco et al. 2015; Velasco et al. 2016b; Woods and Spence 2016), interactivity (Song and Zinkhan 2008; Van Noort, Voorveld, and Van Reijmersdal 2012).	3D-interactive view, virtual try-ons, augmented reality.	Mental imagery (Choi and Taylor 2014; Huang and Liao 2017), telepresence/ immersion (Animesh et al. 2011; Klein 2003; Li et al. 2002; Nah et al. 2011; Yim et al. 2017), enjoyment (Kim and Forsythe 2008a, b; Lee and Chung 2008; Nah et al. 2011; Yim et al. 2017), flow (Animesh et al. 2011; Huang 2012; Huang and Liao 2017; Jiang and Benbasat 2004; Nah et al. 2011; Novak, et al. 2000; Van Noort, Voorveld, and Van Reijmersdal 2012), interactivity (Huang 2012; Yim et al. 2017); self-congruity (Merle et al. 2012), ownership (Bregman et al. 2018; Huang and Liao 2017), need for touch (Bregman et al. 2018; Choi and Taylor 2014), curiosity (Beck and Dominique Crié 2018). Sensory congruency (Hashimoto et al. 2008; Ho et al. 2013; Liu, Hannum, and Simons 2018)
Hearing	Headphones, loud-speaker (music, sound, jingle).	Sensory congruency (Hagtvedt and Adam Brasel 2016; Knoefler et al. 2016).	Multisensory experience with auditory inputs (Food simulator, Straw-like User Interface).	
Touch	Mouse, touchscreen.	Mental imagery (Shen et al. 2016), ownership (Brasel and Gips 2014), affect (Brasel and Gips 2015; Shen et al. 2016)	Vibrotactile interfaces, body-grounded tactile actuators, mid-air haptics.	Need for touch (Brasel and Gips 2014; Cano et al. 2017; Jin 2011), telepresence (Leithinger et al. 2014; Sallnäs, Rasmus-Gröhn, and Sjöström 2000), emotion (Rantala et al. 2013), Midas touch effect (Haans and IJsselstein 2009; Haans et al. 2014; Spapé et al. 2015).
Smell	X	X	Multisensory experience with smell inputs (Season Traveler, MetaCookie+).	Sensory congruency (Ranasinghe et al. 2018; Liu, Hannum, and Simons 2018).

Table 1: Summary of common interfaces and new sensory-enabling technologies.

Another way to incorporate Augmented Reality into the shopping experience would be incorporating it into the physical retail store experience. Tech company Apple Inc. is planning to do just that in 2023, according to rumors. An updated version of their Apple Store app for the iPhone would activate extended AR capabilities upon entering a retail Apple Store. Customers would point their iPhone's at a product in the store and receive extensive information about the device on their phone. The underlying API of the Application would even be opened up to third-party developers, allowing other retail outlets to take advantage of the new technology (Gurman, 2023). While all this research into multi-sensory interfaces is fascinating, the common paradigm of Sight (Monitors), Audio (Headphones and Speakers), and Touch (Mouse and Touchscreen) based interfaces has remained unchanged for close to 50 years (See Figure 2).

HUMAN INTERACTION WITH A COMPUTER

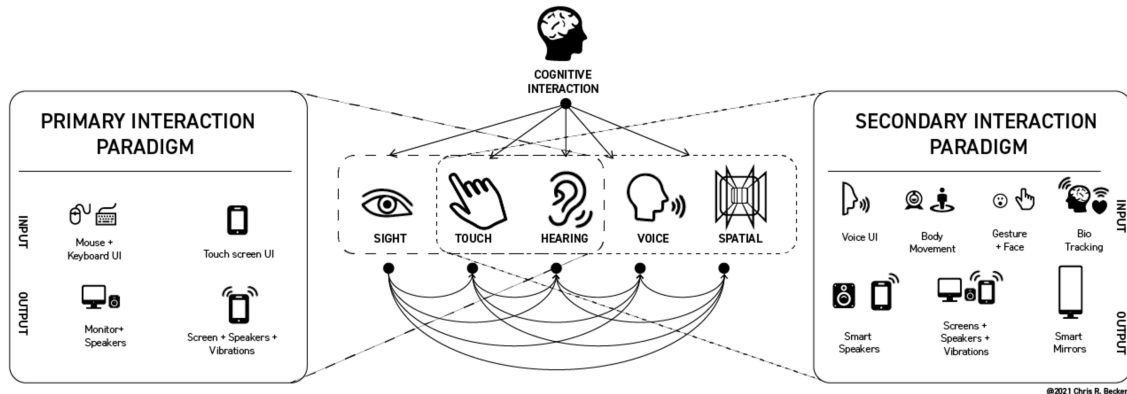


Figure 1: A graph showcasing common sensory interactions with a computer. Source: Becker (2021)

1.2 Neuroimaging-Driven Web Design and the Importance of User Reviews

To allow the consumer to distinguish and to compare products in an e-commerce environment more easily, web developers have paid particular attention to the visual design of their websites (Çelik, Kabak, & Uslu, 2022), their product presentation technologies (i.e., zooming, Augmented Reality, videos) (Kim & Forsythe, 2008), and have introduced useful features into their platforms, such as user reviews. As noted by Cortinas and colleagues (2019), the most complex and time-consuming task for shoppers is the assessment of purchase options. An effective method to modulate executive control over consumers' purchasing decisions is to reduce checkout times to make sure that consumers deliberate less about the items in their shopping carts, increasing the chance that they will be engaged in impulsive purchases (Shiv & Fedorikhin, 1999). User reviews have also been helpful in aiding consumers with their decision-making process, since they are written from the perspective of another consumer like them (Mudambi & Schuff, 2010). The popularity of online reviews in the consumer's decision making process cannot be overstated, as an industry survey from 2011 confirms that 90% of online

shoppers read online reviews, and a further 83% of them believe that reading these online reviews will influence their decision making process (ChannelAdvisor, 2011). A study by Cantalops and Salvi (2014) even highlights the growing trend that users are becoming increasingly dependent on online reviews to minimize perceived risk and doubt in their purchasing decisions. However, in this highly competitive environment, the need and desire for companies and brands to utilize Neuromarketing techniques to discern the consumers' inclination of purchasing a product early on in the decision process remains clear (Kim & Lennon, 2008).

The field of neuromarketing utilizes neuroimaging techniques to perform neuroimaging studies for marketing purposes (Ruanguttamanun, 2014). There have been several definitions for the term neuromarketing: Murphy, Illes & Reiner (2008) describe neuromarketing as “[...] *The use of advanced neuroscience that permits powerful insights into the human brain's responses to marketing stimuli*”. And it has been succinctly described as “[...] *An application of neuroscientific methods to analyze and understand consumer behavior*” (Lee, Broderick, & Chamberlain, 2007). Several technologies are used for neuroimaging purposes, with the most common ones being functional Magnetic Resonance Imaging (fMRI), Eye-Tracking, Transcranial Magnetic Stimulation (TMS) and Electroencephalography (EEG).

CHAPTER 2

APPLICATIONS AND IMPLICATIONS OF NEUROMARKETING

The implications of Neuroimaging for businesses are clear. A study by Ariely & Gregory (2010) emphasizes that what marketers hope for is that consumers have hidden information contained within their brains and subconscious minds, that they cannot fully express or articulate, and that this hidden information could be used not only to influence their purchasing behavior in subtle ways, but also to create a marketing research methodology driven by Neuroimaging data. This way, products could be rapidly tested by companies for their appeal to consumers, and the effectiveness of their marketing campaigns (Hubert & Kenning, 2008). Another concept that Neuromarketers are interested in further understanding is “Customer Loyalty”. Customer Loyalty can be defined as “[...] *A deeply held commitment to rebuy or re-patronize a preferred product / service consistently in the future*” (Oliver, 1999). All of these factors combined give marketing managers the hope that Neuromarketing will assist them in precisely defining the factors that underpin the selection of their brands, and optimize their marketing strategies to increase consumer retention and encourage new consumers to adopt their brands (Al-Kwafi, 2016).

Already, we are seeing the business sector taking the research and theory of Neuromarketing into practice. Companies such as ‘Campbell’ have changed the packaging of their products, guided by Neuroimaging metrics (Brat, 2010). Global corporations like ‘Google’, ‘McDonalds’, ‘Microsoft’, and ‘Coca-Cola’ are conducting their own research into the topic (Ruanguddamanun, 2014). As more research accumulates in the future, more companies are sure to follow.

The purpose of this thesis is to observe and to compare the existing literature on Neuromarketing and online consumer behavior, taking a close look at the two technologies used within Neuroimaging: fMRI and Eye-Tracking. A critical analysis and a look into the future of Neuromarketing will then follow.

2.1 Eye-Tracking for Neuromarketing and Online Consumer Behavior Studies

The fundamental philosophy of utilizing Eye-Tracking methodologies to interpret consumer decision making processes can be traced back to the “Eye-Mind Hypothesis” proposed by Just & Carpenter (1992). They proposed that when an individual is looking at an object, they are currently perceiving and thinking about that particular object, and so we can identify and infer the cognitive processes of an individual by tracking their eye movements. During fixating on an object, our eyes remain relatively static, so tracking fixation is the most effective and efficient way to measure interest in a particular section of an object (Chae & Lee, 2013). This approach to tracking eye-movements has been the foundation for the vast majority of research about visual attention and online consumer behavior. Eye-tracking measures such as Fixation Duration – i.e., the period of time taken to gaze at a given area, typically lasting about 200-250 milliseconds (Negi & Mitra, 2020) – and Time to First Fixation – i.e., how quickly an interest area was first fixated upon, relative to the onset of the image (Neta, et al., 2017) – can all be used to describe a consumers’ interaction with a website or a platform. For example, users not looking at a particular portion of a site may indicate a design flaw (Bergstrom & Schall, 2014). Chen & Song (2022) propose in their study about the factors that affect a consumers’ preference for sneakers sold online, that “[...] Consumers’ purchasing intention associated with

online reviews is moderated/influenced by the level of visual attention.”

There are numerous studies that examine online consumer behavior while utilizing eye-tracking. I believe that the primary reason for this mass adoption of eye-tracking across various laboratories across the world is that using eye-tracking for research is far more affordable than buying and maintaining an MRI scanner. Low cost eye-trackers that mount onto a monitor or laptop are available on the consumer market, and cost as little as US\$259 (Amazon, n.d.). While they are intended primarily for gaming, they can be easily retro-fitted into a laboratory environment to conduct eye-tracking studies. A few gaming-focused laptops are also available, with essentially the same eye-tracking hardware integrated into the laptop itself (Kirkpatrick, n.d.) (See Figure 3).

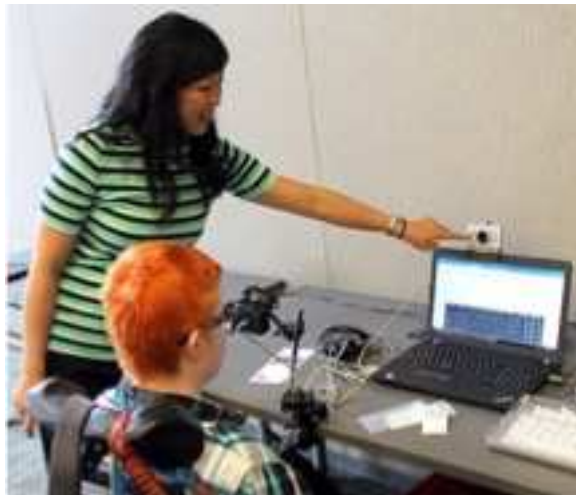


Figure 2: *A mentor shows a student how to use an eye-tracking camera that's attached to a laptop, Kirkpatrick (n.d).*

Eye-Tracking studies involving online consumer behavior pay particular attention to the time spent observing various AOI's of the website or platform. Areas of Interest for online shopping websites can be divided into 3 approximate categories: (i) “The Header” showcases company identity, appears at the top of the website, has a menu with compact details, and generally hosts the “Hamburger Menu” on the left and the shopping cart on the right; (ii) “The Product Offer” occupies the center-screen below the header. This AOI

displays the names, images, and prices of the products being sold; (iii) “Services” appears to the left below the header and link the user to the various pages of the website (Cortinaz et al. 2019).

One particularly interesting research paper by Chen et al. (2022) uses eye-tracking to investigate the impact of online reviews, and the placement of said reviews within the website or platform, on consumers purchasing decisions. Their findings suggest that consumers exert more cognitive attention towards negative reviews than positive ones (See Table 2).

		Whether to buy		Total
		No	Yes	
Review type (more attention)	Positive review	21	25	46
	Negative review	80	34	114
Total		101	59	160

Table 2: Frequency statistics of purchasing decisions. Source: Chen et al. (2022).

They claim that this is consistent with a study by Ahluwalia, Burnkrant & Unnava (2000), which observes that negative information is more valuable than positive information when making a judgement. The notable factor of this paper is that it incorporated the moderating effect of gender. For female consumers, attention to negative reviews was significantly greater than positive ones. Men’s attention was more homogenous, as they paid more attention to positive reviews than women (see Table 3).

Fixed factor	I	J	Fixation dwell time of AOI			Fixation count of AOI		
			Mean difference (I-J)	Standard error	Sig. (p ₁)	Mean difference (I-J)	Standard error	Sig. (p ₂)
Male	Positive reviews	Negative reviews	-916.85	950.68	0.336	-3.34	4.22	0.430
Female			-5072.00*	950.68	0.000	-23.81*	4.22	0.000
Positive reviews	Male	Female	2878.66*	950.68	0.003	9.50*	4.22	0.025
Negative reviews			-1276.48	950.68	0.180	-10.98*	4.22	0.010

*Means significant when $\alpha=0.05$.

Table 3: Results of simple-effect analysis with the added variable of gender. Source: Chen et al. (2022).

Interesting cultural implications arise from these findings. Personally speaking, whether or not these gender differences are due to specific cultural norms and habits; or perhaps some other, more universal factor, could be beneficial to further investigate in the future. Other studies about online consumer behavior that use eye-tracking include topics such as product searching (Luan, Yao, Zhao, & Liu, 2016), the material of shoelaces (Chen & Song, 2022), and the visual behavior of consumers looking at handbags (Ho, 2014).

We can see that online consumer behavior research utilizing eye-tracking is vast and expansive in scope. However, as Wang & Minor (2008) pointed out in their review of the validity and reliability of Psychophysiological techniques in the context of marketing research, studies using eye-movement tracking have not established a psychological basis for the meaning of eye movements (Kroeber-Riel, 1979). One more aspect to note about the reliability of research involving Eye-Movement tracking for online consumer behavior is that a lot of these studies have used students as their subjects, rather than the more desirable target of random consumer samples (Djamasbi, Siegel, & Tullis, 2010). That is not to say that these studies are completely void of merit (they are not), or that there are no eye-tracking studies involving real consumer samples (e.g., (Pieters & Wedel, 36-50)), but I believe that it is important to keep these factors in mind when investigating whether or not eye-tracking would be useful in a particular study or not.

2.2 fMRI for Neuromarketing and Online Consumer Behavior Studies

Functional Magnetic Resonance Tomography (fMRI) is the most widely used technique in the field of brain imaging. The technique uses an MRI scanner to measure the blood oxygenation level-dependent (BOLD) signal (Ariely & Gregory, 2010). The molecule measured in fMRI scans is hemoglobin: an oxygen-carrying molecule which has different

properties depending on its oxygenation state. While oxy-hemoglobin is diamagnetic, deoxy-hemoglobin is paramagnetic, it distorts the magnetic field and causes signal loss. When a region of the brain is activated, increased oxygen consumption is overcompensated by the blood-flow response. Deoxy-hemoglobin is partially replaced by oxy-hemoglobin, and the resulting reduction in distortion increases the signal compared to noise, thus creating detectable patterns of localized activation (Kenning, Plassmann, & Ahlert, 2007). The BOLD changes correlate to underlying synaptic activity within the region of the brain (Ariely & Gregory, 2010). In effect, fMRI allows researchers to view small structures of the brain in good contrast and high resolution, and to localize activation within those structures.

However, research into online consumer behavior that utilizes fMRI is scarce. One primary reason for this lack of research is that the technology is prohibitively expensive. New MRI machines cost approximately US\$1 million, and this can go up to US\$3 million for high-end machines (Excedr, n.d.). And the expenses continue even after purchase. MRI machines have annual operating costs in the range of \$100,000 - \$300,000 (Ariely & Gregory, 2010). Nevertheless, the use of fMRI has been steadily increasing in both business and academic marketing research (Ruanguttamanun, 2014). And this increased use of fMRI has revealed neural correlation for object processing in specific parts of the brain (Al-Kwafi, 2016). For instance, Kenning and Plassmann (2008) suggested that the Ventromedial Prefrontal Cortex (vmPFC) is crucial in the processing of emotions during the decision-making process when comparing various brands. Brain regions involving working memory could sustain reasoning at reduced activation levels. Another fascinating study by McClure et al. (2004) involves Coca-Cola and Pepsi, two brands of soda with near identical chemical composition. When delivered the two drinks

anonymously (without any awareness of the brand), consumers were on an even split in their preferences for either Pepsi or Coca-Cola. When brand awareness was entered into the equation, the Coca-Cola label had a significant impact on not just their expressed preferences, but also on their measured brain responses. Their findings suggested that the hippocampus may participate in recalling cultural information that biases preference judgements. The entertainment industry could benefit from the findings of neuromarketing as well. Hasson et al. (2004) found that, during a shared natural vision, like 30 minutes from the movie “*The Good, The Bad, and The Ugly*”, there is an impressive level of synchronization between individuals’ cortical responses. It is as if these individual brains “tick collectively” during the consumption of natural vision, as they explain.

To my knowledge, there are two research papers that focus specifically on online consumer shopping carried out using fMRI to examine purchasing decision of consumers. The first of these studies, by Jai et al. (2021), applied event-related fMRI to study brain activation before purchase decisions, specifically observing how the brain makes purchasing decisions when it encounters different types of visual presentation strategies of different levels of sensory-engagement, such as a static picture, a zoomable image, and a rotating video. They found that the crucial “buy/not buy” choice can be reliably and accurately predicted by brain activity during the product evaluation period, and that activation patterns were the most reliable in predicting purchasing decision when utilizing the rotating video presentation (See Table 4).

Encoding condition (N = 20)		Test data (Accuracy rate / sig. Level with 500-time permutation)			
		Picture	Zooming	Rotation	Average
Training data	Picture	-	85% $p = .002$	80% $p = .008$	82.5%
	Zooming	80% $p = .010$	-	95% $p = .002$	85%
	Rotation	85% $p = .002$	95% $p = .002$	-	90%

Table 4: Cross-Category validation of whole-brain classification analysis to discriminate between buy/no-buy decisions, utilizing different sets of training data. Source: Jai et al. (2021).

The second research paper by Xu et al. (2020) focuses on the reputation indicators of a seller in an online platform, such as feedback ratings, stars, and other symbols. They use fMRI to determine that these reputation indicators had a statistically significant effect on online decision making. In addition, they found that in absence of detailed information, when consumers need to rely on information signals, both cognitive and emotional responses play a part in the decision making process, particularly by engaging the vmPFC. This finding goes in line with the prior research that we discussed in the section on Neuromarketing studies in general (Al-Kwafi, 2016).

CHAPTER 3

DISCUSSION AND CONCLUSION

With the world now thoroughly entrenched into E-Commerce, amplified by the COVID-19 pandemic, it is now more important than ever for marketers to make sure that their products stand out against competitors in online websites and platforms. Along with conventional web design sensibilities, companies have expressed growing interest in the field of Neuromarketing. In this thesis, I compared existing literature on two technologies of neuromarketing: fMRI and eye-tracking.

Eye-tracking is the most common technology used to study online consumer behavior, as it is affordable, easy to set up, and the post-processing is relatively simple compared to the many layers of data that need to be processed in fMRI studies. However, in my opinion, fMRI represents much more uncharted territory in investigating online consumer behavior. As mentioned earlier, there is very little research about how fMRI could be used to improve the design and usability of online websites and platforms. To me, this suggests untapped potential, and room to explore further in the future.

However there are several limitations of fMRI to consider. The prohibitive costs of operating MRI machines limits their use cases, the mandatory medical environment limits the potential of the types of stimuli that can be applied, and distances the research from the real world use cases that it would supposedly be used for. fMRI has lower temporal resolution than more conventional technologies, like EEG. And the complexity of the neurophysiological processes require deep understanding of the neuroscientific technique being used. There are also ethical concerns to keep in mind. “[...] *The introduction of neuroimaging into an environment in which the ultimate goal is to sell more product to*

consumers may raise ethical issues” (Ariely & Gregory, 2010). After all, the primary purpose of companies, by design, is to maximize their short term profit at all costs, sometimes to the detriment of their own customers and society at large. Would giving these corporations the potential ability to read the minds of their consumers be ethical? It is a fear of mine, as I imagine it is a common fear for many people, that neuromarketing could be used by malicious actors to extract information apart from the specific task being investigated. These questions and ethical ponderings should be a constant wake up call in our minds as researchers of the future.

Overall, the prospect of accessing hidden information in a consumers brain appears to be incredibly rich with opportunities for further growth. Future research in the field of neuromarketing promises deeper insight into the perception of a product by consumers, and the decision making process of said consumers when comparing competing products.

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