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OFFICE OF INSPECTOR GENERAL
UNITED STATES POSTAL SERVICE

Enhancing the Value of Mail: The Human Response

RARC Report

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UNITED STATES POSTAL SERVICE

Executive Summary

Maintaining and enhancing the value of advertising mail is of strategic importance to the Postal Service. The category provides a significant revenue stream for the Postal Service, accounting for over $20 billion — 31 percent of its total revenue — in fiscal year 2014. With an increasing number of choices of media available to marketers, it is imperative that the Postal Service understand the comparative effectiveness of mail using new powerful tools like neuroscience. Such an understanding, based on scientific evidence, would enable the Postal Service to identify growth opportunities.

The U.S. Postal Service Office of Inspector General (OIG) worked with Temple University's Center for Neural Decision Making to conduct a neuromarketing study focused on the differing response to physical and digital media in the consumer buying process, including intent to purchase. Neuromarketing is a rigorous scientific method that explores the consumer's subconscious response — beyond stated preference. In other words, neuromarketing methods reveal actual activity deep in the brain and other physiological responses as opposed to stated answers to survey questions.

The study linked consumers' subconscious responses to three buying process phases:

- **Exposure**. The body's response to an ad;
- **Memory**. How quickly and accurately the brain remembers the ad;
- **Action**. Value and desire for the advertised products — a predictor of purchase.

The results of the study showed that participants processed digital ad content quicker. However, participants spent more time with physical ads. When viewing physical ads, participants had a stronger emotional response and remembered them better. Physical ads, though slower to get one's attention at first exposure, leave a longer lasting impact for easy recall when making a purchase decision. Most importantly, physical ads triggered activity in the area of the brain (ventral striatum) that is responsible for value and desirability for featured products, which can signal a greater intent to purchase.

These findings have practical implications for marketers. If short on time, the digital format captures attention quicker. However, for longer lasting impact and easy recollection, a physical mailpiece is the superior option that could lead to a purchase. This suggests a complementary effect between the two formats that could provide a powerful way for marketers to optimize their media mix, especially as companies look to reach digitally connected customers.

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OIG Synopsis

Introduction

Businesses, which comprise a key U.S. Postal Service customer segment, need to optimize various advertising media to engage consumers and promote sales and customer loyalty. An emerging field, known as neuromarketing, can provide insights into the human response to physical and digital media.[1] The U.S. Postal Service Office of Inspector General (OIG) partnered with the Center for Neural Decision Making at Temple University's Fox School of Business to use neuromarketing methods with scientific rigor to study where and when to effectively use either media in the buying process. This information can help companies of all sizes and across all industries optimize their advertising dollars, especially small businesses often faced with limited marketing budgets.

Since the early 2000s, applied neuroscience research methods have helped researchers study marketing, consumer behavior, and advertising phenomena. Neuromarketing can reveal how consumers consciously and subconsciously process and engage with advertisements to test products, packaging, and marketing messages, as well as the efficacy of various advertising media. Researchers can measure brain and physiological responses to stimuli for a better understanding of why individuals make the decisions they do. Companies such as Google, Disney, and Frito-Lay have used this type of research to measure actual, rather than self-reported consumer response to their advertisements or products.

Strategic Importance

Advertising mail continues to be a major revenue source and profit stream for the Postal Service, not only because of the mail volume the ads themselves generate, but also because it often leads to consumer purchases and additional correspondence between consumers and companies in the form of bills, payments, and packages. This research aims to understand scientifically when mail is more relevant and valuable to recipients and as a result, effective for senders, ultimately elevating the entire mail value chain.

This project explores the consumer's subconscious response, beyond stated preference, to digital and physical media during three of the five specific phases of the buying process. The study focuses on three specific phases (1) exposure to advertising information, referred to as engagement in this study; (2) retrieval of information, or memory; and (3) action, which is purchase, purchase intentions, or willingness to pay. Figure 1 identifies the five main phases of the buying process.

Figure 1: Phases of the Buying Process

This study expands upon earlier neuromarketing efforts. Royal Mail first used neuromarketing techniques in a 2009 study, which showed that physical media generated deeper brain activity than digital media.[2] Royal Mail released a subsequent study in 2015 that included a neuromarketing component as part of a larger mail usage study, which concluded that mail generated stronger responses in terms of engagement, emotional intensity, and memory when compared to email and television.[3]

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1 Neuromarketing combines the insights of multiple disciplines including neuroscience and psychology to answer traditional marketing research questions.
2 Millward Brown, "Using Neuroscience to Understand the Role of Direct Mail," 2009, http://www.millwardbrown.com/docs/default-source/insight-documents/case-studies/MillwardBrown_CaseStudy_Neuroscience.pdf.
3 The Royal Mail, *The Private Life of Mail: Mail in the Home, Heart and Head*, February 2015, http://www.mailmen.co.uk/.

The Royal Mail studies inferred consumer behavior based on a single measure of neurological activity. The OIG effort expanded upon these landmark studies by employing a multi-methodological approach to corroborate results across techniques and link human responses to various phases in the buying process. An extensive academic literature review confirmed that research of this type had not been done previously. The OIG study also connected human response to physical and digital media to the buying process. The project created a life-like environment to review digital and physical mailpieces naturally during the exposure phase, while employing best-in-class neuroimaging methods used by academic institutions for the recall and purchase portions of the testing.

Another goal of this project was to encourage other stakeholders to use this burgeoning field to conduct additional, rigorous neuromarketing research studies of their own. Creating the linkage between neurophysiological measures and the buying process can provide valuable insights for businesses of all sizes and help optimize their media mix to know when to use mail, other digital media, or the two in combination for an effective integrated campaign.

Methodology

The project used survey questionnaires, eye tracking, core biometrics, and neuroimaging (See Table 1) to examine all levels of physiological and neural activity. The study featured two sessions carried out a week apart and culminated with a purchase simulation.[4] During the first phase, researchers exposed participants to the ads and measured their physiological reactions to the material. During the second phase, researchers recorded participants' brain activity when reviewing a collection of new and previously seen ads. Additionally, the researchers measured the value participants placed on the products and services in the ads. Integrating corroborated results by combining multiple methodologies yielded interesting insights backed by thorough analysis.

Table 1: Neuromarketing Tools Defined

Neuromarketing Tool		Research Method	Outcome Revealed
	*Eye Tracking*	A camera and infrared technology monitor eye movements, in terms of speed and duration of attention	Tracks visual attention in reaction to predetermined areas of interest
	*Core Biometrics*	Sensors placed on fingertips measure heart rate, skin conductance (sweat), motion, and respiration	Gauges the depth of emotional engagement
	*Functional Magnetic Resonance Imaging (fMRI)*	Brain scanner measures change in oxygenated blood flow to reveal regional activation during a task or experience	Pinpoints specific deep brain activity beyond surface cognitive function (e.g., empathy and reward)

Source: Temple and OIG analysis.

4 All participants in this study volunteered and were compensated for their time and participation. The Temple University Institutional Review Board reviewed and approved all steps of this study's methodology to ensure the protection of the participants' rights, dignity, and welfare.

Phase I: Viewing Physical and Digital Ads

In the first session, the exposure phase, study participants viewed different physical and digital ads. Physical ads were printed on postcards while digital ads were embedded into different emails placed inside an email box created for this study (see Detailed Analysis Appendix C). Each ad promoted a product, such as headphones, a service, such as Hulu, or a local restaurant. While viewing the ads, eye tracking and biometrics (skin conductance and heart rate) equipment captured what participants looked at and for how long, as well as the participants' physiological response or emotional engagement associated with the hard copy and digital ads. After viewing the ads, participants answered survey questions that revealed their preferences and recollections about the ads and their contents.

Phase II: Testing Memory and Willingness to Pay

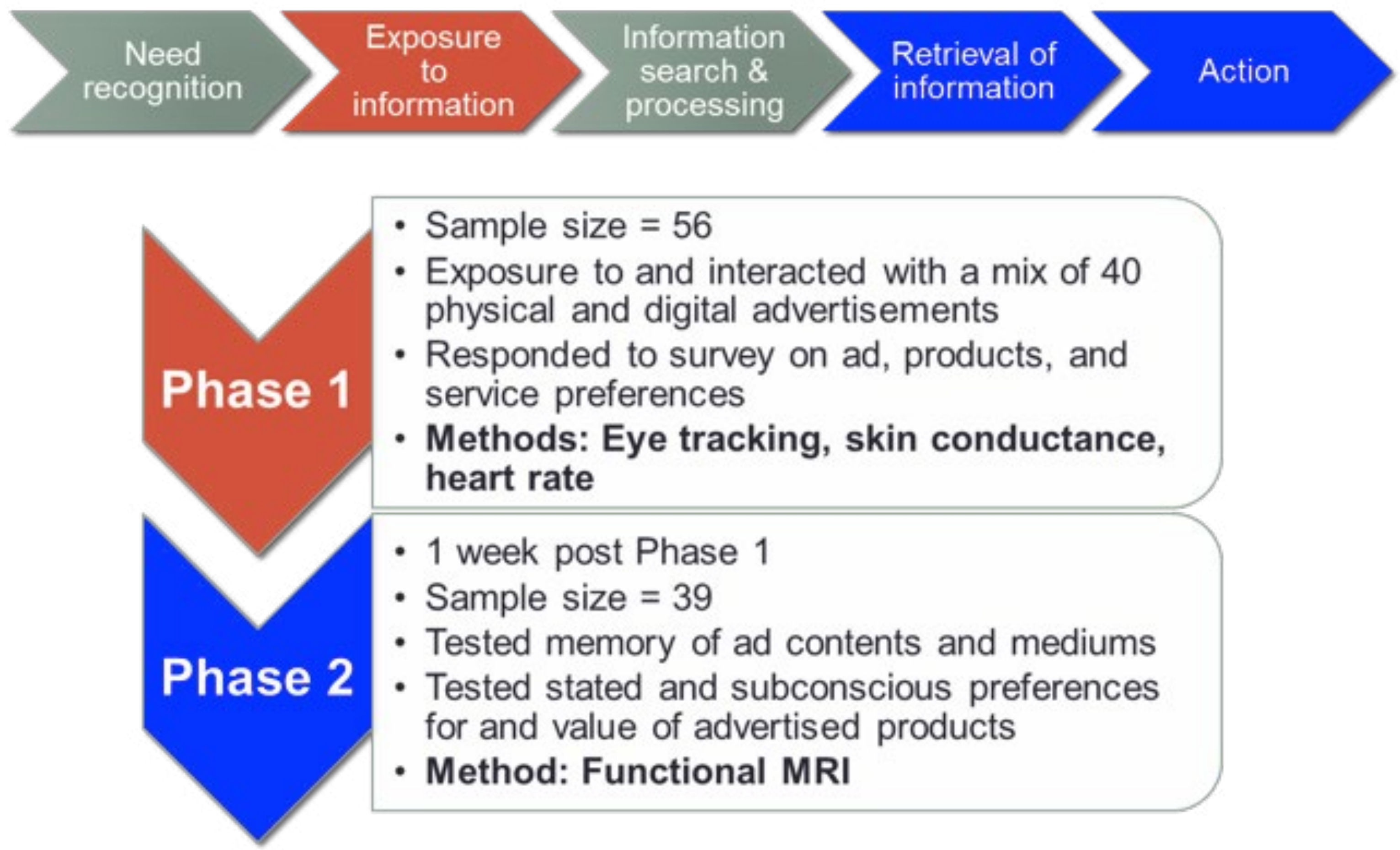
The second phase employed a functional magnetic resonance imaging (fMRI) scanner to capture participants' brain activity while answering questions about their current and prior exposure to the advertisements. Participants first reviewed a series of ads and identified whether or not they had seen them a week before, including which context the ad was presented to them in (i.e., physical or digital). Afterwards, participants underwent a simulated purchase process in order to understand the subconscious value and purchase reaction that occurs in real life.

For the simulation, participants indicated how much they would be willing to pay for each of the items or services in the ads, knowing they could actually buy it at the end of the study using the compensation they would receive. Participants had to report the amount they were willing to pay. If that amount was higher than a randomly assigned dollar amount, they would be able to purchase the item for that amount. This auction method, commonly used in economic research, incentivized participants to be as realistic as possible about how much they would be willing to pay for an item. The fMRI captured the brain activity associated with the decisions — cognitive or otherwise.

Figure 2 summarizes the two project components and illustrates how they aligned with the specific phases of the buying process.[5]

5 The neuroscience community accepts the standard of 30 subjects to provide statistically significant results.

Figure 2: Methodology Summary Linked to the Buying Process



Source: Temple and OIG analysis.

Findings

The study resulted in a number of key findings:

- Self-reported survey results demonstrated little difference between participants' preferences for or attitudes toward ads presented digitally or physically.
- Participants chose to review physical ads longer than digital ads, but exhibited more focused attention on specific elements of the digital ads. Thus, if a busy consumer only has 10-20 seconds to view advertisements, a company is more likely to get its message across quicker through digital, rather than physical, ads.
- Despite the differences in amount of time spent with digital and physical ads, participants actually absorbed the same amount of information from both media.
- Physical ads had a longer lasting impact than digital. A week after the initial viewing, the emotional response and concrete memory of the physical ads allowed participants to more quickly and confidently remember the physical ads than digital ads. This may be crucial when making actual purchases.

- Although participants stated similar preferences and willingness to pay for an item regardless of whether they saw the ad in a physical or digital format, their brain activity indicated greater subconscious value and desire for products or services advertised in a physical format. Previous research indicated that activity in this portion of the brain (the ventral striatum), responsible for valuation and desirability, was a strong predictor of purchases, which merits further research.

The following table summarizes which media better achieved specific advertising goals.

Table 2: Outcomes by Media Type Summary

Attribute	Definition	Physical	Digital
Attention	A customer's focused attention for a sustained period of time on key components of the ad		X
Review Time	The amount of time a customer spends with an ad	X	
Engagement	The amount of information the customer processes or absorbs from an ad	X	X
Stimulation	An emotional reaction to an ad	X	
Memory Retrieval Accuracy	Accurately remembering the advertising source and content	X	X
Memory Speed & Confidence	Quickly and confidently remember advertising source and content	X	
Purchase & Willingness to Pay	Whether and how much the customer is willing to pay for a product	X	X
Desirability	A subconscious desire for the product or service	X	
Valuation	The subconscious value a participant places on the product or service	X	

Source: OIG analysis of study results.

The Path Forward: Suggestions for Future Work

These results invite further neuromarketing investigation regarding the importance and efficacy of digital and print media because 1) human responses continue to evolve and adapt with evolving media and 2) additional research can help companies better understand the subconscious response to areas previously explored by traditional means. Some potential areas of consideration include

- **Analyzing age cohort or other demographic-specific responses to media type.** Companies could fine-tune their marketing spending by better understanding what mix of media (including TV/radio) can best reach their target audiences.
- **Understanding the effectiveness of specific advertising elements like color, size, and use of white space.** Stakeholders may want to test how specific elements of a direct mailpiece — color, shape, fonts, and use of white space — affect both the physiological reaction and consumer behavior for optimum impact.
- **Exploring sequencing in a mixed-media campaign.** Marketers could use neuromarketing techniques to determine the most effective sequence of media to optimize a given campaign. For example, they could test whether an email followed by a direct mailpiece, or vice versa, generates a stronger response. Other media types, like television, could be included in potential studies.
- **Studying the value of embedded digital technology in print.** Previous OIG focus group work showed that Digital Natives responded well to print formats embedded with digital technologies such as Quick Response or QR codes, Augmented Reality, and Near Field Communications.[6] The Postal Service recognizes that digital elements in mailpieces better engage consumers, and currently offers promotions to mailers that incorporate digital elements in mail. Understanding the underlying physiological and neurological impact of merging digital and physical elements could be extremely powerful for marketers.

Conclusion

Marketing and advertising decision-makers want to know where physical and digital media are most effective in the consumer's buying process. While participants in this project showed no preference between physical and digital advertising when responding to surveys, neuromarketing techniques revealed different subconscious physiological responses among participants. The study indicated that digital ads may provide a cost effective option for companies that are trying to get consumers' attention to quickly understand a marketing message. However, companies that want to generate a more accurate memory of an ad, for better recall during a purchase, would be served best by physical ads. Additionally, the research showed that physical ads generate brain activity associated with a higher perceived value and desirability of the advertised product or service. Recent research shows that activation in this area (ventral striatum) during product evaluation is the strongest predictor of real-world market behavior, like purchases and sales.

Although physical communications can have a greater subconscious effect than their digital counterpart in many regards, digital communication presents its own strengths, and the complementary nature of the two formats can provide a powerful media mix. By understanding the underlying neurological responses and revealed preferences of recipients through carefully controlled neuromarketing studies, companies can use this new type of research to learn how each media purchase can be optimized in an integrated marketing campaign.

6 U.S. Postal Service Office of Inspector General, *Enhancing Mail for Digital Natives*, Report Number RARC-WP-14-001, November 18, 2013, https://www.uspsoig.gov/sites/default/files/document-library-files/2013/rarc-wp-14-001_enhancing_mail_for_digital_natives.pdf.

Detailed Analysis

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Understanding the Effectiveness of Physical Mail Communications Through Neuroscience

Angelika Dimoka, Khoi D. Vo, Vinod Venkatraman, Paul A. Pavlou
Center for Neural Decision Making
Fox School of Business, Temple University
June 15, 2015

Abstract

Despite the growing popularity and complexity of managing marketing and advertising communications across physical and online media channels (often referred to as cross-media marketing), little is known about the effectiveness of each of these channels of communication and their impact on the consumer buying process. In this study, we used a multi-methodological approach utilizing traditional self-reports, eye tracking, biometrics (heart rate and skin conductance), and neuroimaging (fMRI) to better understand how consumers process physical versus digital advertisements. Crucially, we were interested in studying the impact of the two different media on consumer's memory of the ads and preferences at a subsequent point of purchase. Therefore, the study was conducted over two separate experimental sessions with the same set of participants. Both experimental sessions occurred approximately one week apart.

In the first session (Phase 1), participants were exposed to a mix of 40 different physical and digital ads. Traditional self-report measures were collected to measure preferences and attitudes about the ads and their contents. Eye tracking and biometrics (skin conductance and heart rate) were used to capture process data (what participants are looking at) and physiological responses when participants interact and engage with the physical and digital ads. Integrating results across the methodologies in Phase 1, we found that digital ads were associated with greater attention and more systematic processing than physical ads. However, this difference in attention did not mean participants were less engaged when interacting with physical ads. In fact, the level of engagement to key components of the ads, such as the products and/or brands featured, was similar across both formats. Additionally, we found that physical ads elicited greater levels of arousal than digital ads. In other words, participants were more emotionally engaged and interested when interacting with physical ads.

In the second session (Phase 2), memory retrieval (item and source memory) of the 40 ads was assessed. Additionally, preferences and purchase intentions for the advertised items, such as products, services, and restaurants, were assessed in an incentive-compatible manner. In order to understand whether the differences in levels of attention and arousal between the two formats were associated with greater depth in processing and memory during subsequent purchase decisions, we used functional magnetic resonance imaging (fMRI) in Phase 2 to study memory retrieval (item and source memory) and purchase intentions or willingness to pay (WTP) for the products and services featured in the ads. We found that participants were more likely to remember an ad and its context if they were previously exposed to it in the physical format. This behavioral difference was corroborated by increased activation in the hippocampus and parahippocampal place area (PPA) during memory retrieval for physical relative to digital ads. With respect to stated preferences, there were no differences in the self-reported purchase intentions or willingness to pay for the items featured in the ads based on prior exposure. However, we found increased activation in the ventral striatum when participants were estimating their WTP for items previously exposed in the physical relative to digital format. Based on prior results and the role of this region in reward processing and desirability, we argue that items are perceived as more valuable and desirable to the consumer when they were exposed to them previously in a physical ad. We discuss in this paper the implications of these findings for marketing campaigns and cross-media communications.

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Introduction

Since the early 2000's, there has been a rapid growth of neuroscience research and the application of neurophysiological methods to the study of marketing, consumer behavior, and advertising phenomena, broadly referred to as *neuromarketing*, or *consumer neuroscience*, or more broadly decision neuroscience (e.g., Ariely & Berns, 2010; Camerer, Loewenstein, & Prelec, 2005; Dimoka, 2012; Smidts et al., 2014; Yoon et al., 2012; Venkatraman et al.. 2012; Venkatraman et al., 2014). Neuromarketing has burgeoned into a completely new field of research that is accepted by both academics and practitioners alike. Moreover, a new industry has also been built around neurophysiological tools in marketing phenomena in practice. This growth is largely due to the demonstrated value of neurophysiological tools to study marketing and other practical phenomena, technological advances in functional magnetic resonance imaging (fMRI), electroencephalography (EEG), eye tracking, and other neurophysiological tools (i.e., biometrics), and the accessibility of these methods with decreased costs (Dimoka, Pavlou, & Davis, 2011).

Besides the potential for integrating neurophysiological methods into the marketing research toolbox, there is much potential for integrating different media used in marketing communications, such as physical and online media in marketing campaigns. C*ross-media marketing*[1] is an important mechanism for companies to reach new customers, identify potential customers of new products, or retain the loyalty of existing customers. Due to technical advancements in online communications, many online platforms, such as direct e-mail, online social media, and social networking sites (e.g., Facebook), have become more important to companies pursuing integrated cross-media campaigns (at the expense of print advertisement). In this study, we focus on two marketing channels: direct mail and electronic mail.

In 2007-2008, the U.S. Postal Service commissioned comScore Networks to study the effectiveness of direct mail in driving sales. This study found that recipients of direct mail, such as catalogs, were more likely to make purchases and spend more money in online sales relative to people who had not received direct mail catalogs. This study also argued that direct mail helps strengthen a brand, especially through direct marketing to targeted consumers in a local market, compared to digital campaigns that often reach a more heterogeneous groups of consumers and are not always as applicable for the intended recipients. When used as part of a cross-media marketing campaign, direct mail plays a synergistic role in promoting awareness of digital content (i.e., related websites), driving online traffic, and increasing online sales.

Similar to comScore Networks, many practitioners, as well as academics, have taken notice of the importance of cross-media marketing research over the past decade. However, most studies have analyzed cross-media marketing campaigns using only traditional methods, such as self-reported surveys. There is a dearth of research at the neurophysiological level needed to better understand the underlying neurological drivers of consumer behavior in response to print and online marketing communications to better predict actual behavior. Furthermore, to our knowledge, there exists no

1 In this study, we use the term *cross-media* when referring to marketing campaigns that require more than one medium to disseminate their communication messages. More specifically, we will focus on direct mail versus digital communication.

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research that looks at the effectiveness of cross-media marketing using neurophysiological tools across the different stages of the buying process, which we simplify below:

1. Information search and processing (e.g., looking at advertisement contents and engaging with advertising content)
2. Retrieval of gathered information (e.g., recall/recognition) during the product evaluation stage
3. Action (e.g., response rate, purchase intent, or willingness to pay)

In 2009, the Royal Mail commissioned Millward Brown and their academic collaborators from Bangor University to study how consumers process physical media (i.e., print and direct mail) relative to their digital counterparts using fMRI. To our knowledge, the *Millward Brown Case Study: Using Neuroscience to Understand the Role of Direct Mail* (herein referred to as the "Millward Brown" study) was the first study to attempt to look at differences between physical and digital marketing materials using neurophysiological methods (i.e., fMRI). The Millward Brown study found that physical media left a "deeper neural impression" compared to their digital counterparts. Physical media elicited greater cognitive and affective processing, relative to digital ones. However, although the Millward Brown study found greater cognitive and affective processing of print relative to digital advertising, no attempts were made to relate the underlying neurophysiological differences to actual measures of campaign success. In other words, the Millward Brown study did not address whether or not these captured neural differences led to differences in memory retrieval of physical marketing stimuli and their contents, as well as differences in purchase intentions for the advertised contents.

The Royal Mail commissioned a second study recently (2015) to further study the effects of physical marketing communication. As mostly an ethnographic and observational effort, this study included a component that analyzed neural activity using EEG during the mail moment. Based on the results of this component of the Royal Mail study, physical mailers elicited stronger engagement, emotional intensity, and long term memory encoding at the point of mail interaction based on Neuro-Insight's SST measures. However, similar to the Millward Brown study, this second Royal Mail study did not go beyond the implications at the mail moment. Although the study mentioned how physical mail influenced preferences, it was unclear whether or not this study assessed the impact of physical advertisements on consumer's memory and preferences beyond the moment of ad exposure and further into the consumer buying cycle at a later time.

In order to address and extend the results from the Royal Mail studies and the USPS/comScore study, a multi-phase, multi-methodological study was conducted to examine the effects of direct mail and digital campaigns on consumers during the different stages of the buying process from initial exposure and processing, to retrieval, and to actual behavior. This study assessed the impact of direct and electronic mail advertisements on consumers by capturing underlying neurophysiological responses during and post advertisement exposure to better understand the cognitive and affective processes that underlie information exposure and acquisition, as well as the retrieval of such information. In addition, this study seeks to address the gap in the Royal Mail studies by linking these underlying neurophysiological responses to measures of marketing campaign success, such as successful memory retrieval and actual purchasing behavior at a later time post ad exposure.

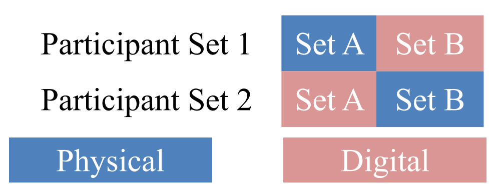
Methodology

Phase 1: Eye Tracking, Biometrics, & Traditional Behavior
Phase 1 of this study is the main exposure phase, where moment-to-moment data were collected while participants were exposed to and interacted with physical or digital ads[2] in the lab (40 stimuli, 20 physical and 20 digital). Physical ads were printed on postcard with similar sizes to postcard mailers (6 x 9 in postcards) while digital ads were embedded into different e-mails placed inside an e-mail box created for this study (see Appendix C). Each ad promoted a product (e.g., headphones), a service (e.g., Hulu), or a local restaurant (e.g., Jamonera). Additionally, to provide more variability and to mimic real world clutter for physical ads, a set of 6 ads normally received in the mail were added, such as a postcard mailer from a cable company or a postcard with coupons for an oil change.

During the exposure, ads were shown by block (i.e., physical or digital block) and the order of block presentation was counterbalanced across all participants. For the task, participants were asked to help the experimenter evaluate different ads for products, services, and restaurants. Specifically, participants were asked to think about how much they like the ad, whether or not they are interested in purchasing the item advertised, and other attitudes and opinions about the ads that they may have. Participants were told they could provide their feedback in a structured questionnaire conducted at the end of the study. This set of instructions ensured participants were more aware that they needed to interact with the ads they are given and to spend some time with each ad.

While participants were interacting with the ads, they also had their eye gazes tracked using eye-tracking technology – specifically, a Tobii T60XL for digital ads and a Tobii X2-60 for physical ads. Skin conductance and heart rate were measured using BioNomadix wearable wireless sensors from BIOPAC to ensure that participants were comfortable and not limited in their mobility during the experimental session. The 40 advertisement stimuli were equally divided into two sets where half the ads were assigned as a digital ad or a physical ad, which was counterbalanced across participants. For example, if an ad was assigned to be displayed in the physical condition in Set A, then the same ad is assigned to be displayed in the digital condition in Set B. Below is a depiction of the set assignment.

Figure 1. Depiction of between-subject design in Phase 2b.



2 The terms “ad”, “advertisement”, and “stimulus” (pl. stimuli) are used interchangeably in this report. Each stimulus that participants see is an advertisement piece that was either created by various media agencies or by the experimenters conducting this study. Because some stimuli were created in-house by the experimenters, they were pre-tested for any unintentional effects that could affect overall study results.

After being exposed to all ads, participants were asked to provide opinion ratings for the items advertised in the stimuli and their preferences for these items. Additionally free recall was recorded from all participants, in which participants had five minutes to recall any ads that they saw during the study. Eye tracking and physiological recordings were not done during the final questionnaire portion.

Phase 2: fMRI

Approximately one week later (5 – 7 days), participants from Phase 1 who were cleared for MRI research are asked to come back for Phase 2 of the study. During Phase 2, participants completed two tasks inside the MRI scanner while having their functional data collected by a Siemens MAGNETOM Verio 3T MRI system.

There were two purposes for this phase of the study. The first purpose was to assess memory and examine if and how well participants retrieved information from the marketing communications they were exposed to a week prior either in the digital or physical format. Knowing whether or not consumers remembered an ad and its contents is important information for marketers as they assess advertising effectiveness. Additionally, it is also important to know how the context, or media, influences how well consumers form their memories and preferences about advertised products. Of course, understanding consumer preferences and valuation of advertised products is also critical for marketers. The second purpose of Phase 2 was to assess preferences for the 40 items (products/services/or restaurants) promoted in the advertisements participants were exposed to the week prior. Phase 2 also assessed how physical or digital ads influenced consumer preferences and valuation of the different advertised items.

As a common practice in memory research, 50% of the ads during memory retrieval task were foil ads (n = 20).[3] Inside the scanner, ads were presented one by one and participants were asked to identify whether or not they remember seeing each ad a week ago. If they have seen an ad, they were to classify it as *old*. For an ad they had not seen before, participants were to classify it as *new*. Participants also provided a confidence rating for each response by qualifying their response as either *definitely* or *probably old/new*. Additionally, if participants identified an ad as *old*, they were also asked with a follow-up question to recall if they were exposed to the ad in the *physical* or *digital* context (i.e., postcard or e-mail). Again, participants could qualify their responses with either *definitely or probably physical/digital*.

During the preference task, participants looked at the items individually and provided their willingness to pay (WTP) to receive the item if afforded the chance. In fact, participants were instructed that, at the end of the study, they would have a chance to purchase an item that they see using the endowed amount that they have earned for enrolling in both phases of the study ($50). To make the purchasing task incentive compatible (i.e., real purchases), we applied the Becker–Degroot–Marshak auction method (Becker, DeGroot, and Marshak, 1964; herein referred to as BDM). The BDM method is a widely used method in consumer behavior and decision neuroscience research to ensure incentive compatibility. The auction rules are as following:

3 Foil stimuli are advertisements that participants were not exposed to during Phase 1. These foils were chosen to either match the ones used during Phase 1 or were completely different from any stimuli used in Phase 1 and were meant to provide variability during the memory task.

1. After completing the task in the scanner, an item from the set of items used in the study is randomly selected for auction.
2. A dollar amount ($X, purchasing price) is randomly selected from a 6x6 price matrix filled with prices randomly drawn from a distribution of $1 up to $50.
3. If the participant's WTP > $X, he will be able to buy the product and will pay $X, the purchase price set in step 2. In other words, participants are told that the willingness to pay they provide inside the scanner for each item is the maximum budget they would allow themselves to purchase each item. Thus, if the purchasing price $X is less than their WTP, they have enough money in their budget to buy it. If this is the case, participants buy the item at $X and keep the remainder of their endowment.
4. If the participant's WTP < $X, they will not get to buy the product and will pay nothing. In this situation, the participant's budget to buy the item is too low and thus the purchasing price $X is too expensive. If the auction fails to materialize, the participant gets to keep their full endowment.

Table 1. Methodologies

Eye Tracking (ET)	In terms of neurophysiological tools, eye tracking is perhaps the most accessible method for capturing the consumer's visual processing and attention. Eye tracking has a high temporal resolution (60-120 Hz) and provides insight into temporal processes. Compared to old camera-based systems (with chin rest and head straps), modern eye trackers use an optical camera to identify the position of the pupil and cornea using infrared (IR)/near-IR light that evokes corneal reflection. Besides capturing process data with eye tracking, such as where participants are focusing on and in which order, pupil size can also be recorded and used as a measure of arousal. For more information on eye tracking research, see Wedel & Pieters (2008).
Heart Rate (HRV)	Heart rate variability (HRV) analysis looks at the beat-to-beat heart rhythms, which can be captured by quantifying the electrical activity of the heart. This electrical activity is typically measured via an electrocardiogram (EKG) using external skin electrodes. Heart rate is controlled by two antagonistic branches of the autonomic nervous system: the sympathetic nervous system (SNS, fight-or-flight system) and the parasympathetic nervous system (PNS, rest-and-digest system). By the nature of the physiological systems directly affecting heart rate, heart rate acceleration is controlled by the SNS and provides an independent measure of arousal. Increased heart rate deceleration is controlled by the PNS and indicates an increased ability to focus on external stimuli, indicative of greater attention. For more information on heart rate variability, see Potter & Bolls (2011).
Electrodermal Activity (EDA)	Electrodermal activity occurs when the skin transiently becomes a better electrical conductor due to increased activity of the eccrine (sweat) glands following exposure to external stimuli. Such activity is directly influenced by the sympathetic nervous system. Thus, skin conductance is frequently used as a tool to measure tonic activity of the SNS, called skin conductance level (SCL). Phasic skin conductance activity, which is the modulation of the tonic signal as a response to external stimuli, is called skin conductance response (SCR). Due to the nature of physiological responses, SCR's are indicative of arousal during stimulus exposure. However, SCR's cannot reliably indicate emotional valence. For more information on electrodermal activity, see Potter & Bolls (2011).

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Functional Magnetic Resonance Imaging (fMRI)	Functional magnetic resonance imaging (fMRI) is a non-invasive method that localizes and tracks changes in blood oxygenation during cognitive tasks. The blood oxygenation level dependent (BOLD) contrast is based on the fact that hemoglobin has different magnetic properties depending on its oxygenation state. Since neural activity following a specific task utilizes oxygen within specific areas of the brain, the brain vasculature responds by increasing the flow of oxygen-rich blood into the region. This leads to a localized increase in BOLD signal intensity in that region of the brain, which is then measured using high-field magnetic resonance scanners. Accordingly, fMRI provides an indirect and correlative measure of local brain activity at high spatial resolution (about $1mm^3$) and good temporal resolution (about 2-5 seconds). Using fMRI, we can capture neural activations from the whole brain that can be used as direct measures of memory, desirability, engagement/attention, and affect/arousal. For more information on fMRI, see Huettel, Song, & McCarthy (2008).

Core Constructs of Marketing Effectiveness

The success of any marketing campaign is measured by how it translates to real-world market outcomes. We argue that the key is to demonstrate the impact of the campaign – whether promoted via print media or digital media – on measurable behaviors like the retention and recall of information, such as products and brands advertised, and eventual purchases. These behaviors fall into two broad constructs of measures we have previously defined in another advertising effectiveness study (Venkatraman et al. 2015): memory and desirability. Additionally, a more thorough analysis of marketing productivity in terms of memory and desirability requires additional knowledge of other measureable consumer responses that can be broadly defined under the constructs of attention/ engagement and affect.

Accordingly, this study proposed a framework that integrates neurophysiological tools (eye tracking, biometrics such as heart rate and skin conductance, and fMRI) with traditional self-reported measures to provide a comprehensive understanding of these constructs. Specifically, this integrative approach was leveraged to better understand the cognitive (e.g., attention, memory, desirability) and affective (e.g., arousal) processing of print and digital media in marketing campaigns. Each methodology in the framework provides independent measures for the different constructs aforementioned. Thus, results from one methodology can provide valuable insights into the results of another, allowing greater granularity and reliability in ensuing interpretation of the study's findings. The constructs are further defined in Table 2.

For all participants, traditional self-reported measures were collected in both Phases 1 and 2. In Phase 1, the measures include attitude measures for the ad, such as familiarity, liking, and relevancy; and attitudes for the advertised items, such as purchase intention pre and post ad exposure. In Phase 2, measures of item and source memory responses, including preferences for all items used in the study via willingness to pay, were recorded. Self-reported data can be used to infer about affect, memory, and desirability at the behavioral, processed-response level. However, these measures provide an incomplete assessment of these constructs and no assessment of attention/engagement. Other measures derived from the neurophysiological data are described below. Additionally, Table 5 shows the contribution of each methodology to assessing a specific construct, while

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Table 4 provides an abbreviated list of key measures from each methodology and their role in assessing the different constructs. For an expanded list of key measures, please see Appendix A.

Table 2. Constructs and Key Measures

Construct (Phase Tested in Study)	Description	Key Measures
Attention/ Engagement (Phase 1)	Attention is a key factor for driving behavior. In classical marketing research models, the AIDA[4] model (Strong 1925), attention is the first step in the consumer buying process. If a particular media channel does not engage a consumer, it is likely to lead to poor memory encoding and retrieval of the marketing contents, as well as decreased levels of desirability and action. Thus, the inability to capture and engage an audience by the marketing medium will not translate to success in the market place. Although used interchangeably, we make a small distinction between engagement and attention, such that attention is closer aligned to awareness and engagement is closer aligned to mental arousal. In other words, increased attention does not always yield increased engagement. Specifically, attention is defined as the ability to focus in a sustained manner. However, engagement is defined as sustained focus on key components of the ad, such as the product and brand, which is indicative of heightened processing during ad exposure. This is a hard distinction to make and we only do so when interpreting eye–tracking results.	Despite its tremendous importance, there are no reliable or objective means to measure attention/engagement with traditional self-reported measures. Researchers have used measures such as liking as a proxy of attention, but it is not necessarily the same. As a proxy, liking can also represent other cognitive (e.g., desirability) and affective (e.g., emotional liking) aspects. However, eye tracking can capture overall attention through measures such as exposure time, fixation data, and average time spent per fixation (dwell time). Using location information from fixation data, specific level of engagement, such as the information (e.g., product and brand) that is being processed during ad exposure can also be captured. Attention (engagement aside) can also be captured at the physiological level by measuring how heart rate changes. Specifically, increased engagement has been characterized by an increased deceleration of the heart rate and greater variability in heart rate activity. Heart rate deceleration and variability is regulated via the parasympathetic nervous system (PNS, or rest-and-digest system), a branch of the autonomic nervous system that regulates activities while the body is at rest, which is associated with increased cognitive intake and indicative of heightened attention. Parasympathetic tone is linked to signals within the high frequency (HF) band of heart rate signal and can be inferred from the amount of variability in the inter-beat intervals.

4 AIDA is an acronym for attention/awareness, information, desirability, and action.

Construct (Phase Tested in Study)	Description	Key Measures
Affect (Phase 1)	Affect is a broad term that encompasses moments of emotional and physiological responses. Along these two dimensions, we identify two independent components of affect: valence (relative emotional response such as approach/avoidance) and arousal (physiological and subjective intensity). Different affective states can moderate consumer engagement, memory, and behavior. Thus, it is important to understand the consumer's affective states as s/he engages with marketing materials and how such engagement can lead to increase or decrease in information processing of the marketing contents. Affect, in the context of physiological responses in this study, focuses on the arousal dimension and is used to describe a heighten stage of emotional connection and interest during greater arousal.	With traditional self-reported measures, affect was often considered merely a means for attracting attention or engagement. Thus, they have often been inferred with self-reported measures like liking and excitability (Poels and Dewitte 2006; Walker and Dubitsky 1994). These measures represent post-hoc introspection about the valence dimension of affect, experienced from an earlier stimulus, and thus could be distorted by a variety of factors, including higher cognitive processes. However, with self-reported measures, moments of heightened arousal cannot be identified. Eye tracking, specifically pupillometry, and biometrics (skin conductance and heart rate), can be employed to provide a more direct measure of affect along the arousal dimension. Unlike attention, arousal is regulated by the sympathetic nervous system, an antagonistic branch to the PNS in the autonomic nervous system that regulates the body's fight-or-flight responses during moments of heightened arousal. Increased sympathetic activity causes greater pupil size dilation, increased heart rate acceleration, decreased heart rate variability, and greater skin conductance activity. Greater sympathetic tone is linked to signals within the low frequency (LF) band of heart rate signal. Greater skin conductance activity can be characterized using the tonic skin conductance activity (skin conductance level, SCL) and phasic modulation of the tonic signal (skin conductance response, SCR).
Memory (Phase 2)	A key focus of any marketing campaign is its ability to increase memory (i.e., retention and retrieval) of the associated brand or product. Memory refers to the mechanisms by which past experiences influence behavior. If consumers cannot remember or retrieve aspects of the campaign beyond the time of exposure, it is bound to have little or no impact on actual market outcomes. Memory is often associated with encoding, which occurs during the time of exposure; consolidation, which occurs during the intervening period following exposure; and retrieval, which occurs at a period post-exposure. Retrieval success is often used as a proxy for the depth to which information was encoded (Mandler 1980), which is a critical measure of the effectiveness of the marketing material. Additionally, the context in which memories are formed, such as physical or digital exposure, also plays an important role in how well encoding and consolidation can occur.	Besides evaluating self-reported item and source memory of the different ads participants saw in this study, functional MRI can be utilized to capture neural activations at the whole brain level and also activations in specific regions of interest (ROI) that have been implicated in memory retrieval, such as hippocampus and dorsolateral prefrontal cortex. Additionally, we also aim to capture the impact of the context (i.e., physical or digital ad) during retrieval by examining activations in the parahippocampal place area (PPA).

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Construct (Phase Tested in Study)	Description	Key Measures
Desirability (Phase 2)	Perhaps the most important measure of success of any marketing campaign is how it translates to actual purchase behavior. Pertinent to this study, is a consumer more likely to make a purchase after looking through a physical ad or its digital counterpart? In traditional advertising research, desirability refers to the extent to which people desire the product featured in the advertisement. Since it is difficult to measure purchase in experimental studies, researchers have often used intent to purchase or willingness to pay as proxy measures for real market performance with reliable accuracy (Morwitz, Steckel, & Gupta, 2007). Yet, several concerns exist regarding traditional measures of desirability. First and foremost, these measures can be affected by prior knowledge and biases for or against a brand, which is a conflicting effect of brand equity, not the ineffectiveness of a particular marketing material (print or digital). Furthermore, consumers are not completely capable of perfectly predicting the future, neither in terms of how they represent their intentions nor how these intentions will change over time. In other words, the strength of the traditional desirability measures depends on the context, novelty and specificity of the stimulus concerned. (Morwitz & Fitzsimons 2004).	In order to study the effectiveness of print and digital advertising on influencing desirability beyond explicit, revealed preferences, the underlying neural mechanisms of preferences and desirability (i.e., subjective values) must also be considered. Using fMRI, different ROI's implicated in preference formation (ventromedial prefrontal cortex, or vmPFC) and reward processing and subjective valuation (ventral striatum, or vSTR) are examined beyond the whole-brain analysis. The vmPFC has consistently been linked to willingness to pay for a wide range of branded products across different studies (e.g., Plassmann, O'Doherty, & Rangel, 2007; Plassmann, Ramsøy, & Milosavljevic, 2012). Recent research has shown that activation in the ventral striatum during product evaluation is the strongest predictor of subsequent purchases (e.g., Berns & Moore, 2012; Knutson et al., 2007). Furthermore, activation in the vSTR was also implicated to be the strongest predictor of real-world market behavior, such as sales (Venkatraman et al., 2015) or willingness to pay (Linder et al., 2010).

Table 3. Methodology Involvement by Construct

Constructs	Engagement	Affect	Memory	Desirability
Traditional	–	✓ (valence)	✓	✓
ET	✓	✓ (arousal)	–	–
HRV	✓	✓ (arousal)	–	–
EDA	✓	✓ (arousal)	–	–
fMRI	–	–	✓	✓

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Table 4. Abbreviated Table of Key Measures by Construct

		Attention/Engagement	Arousal	Memory	Desire/Intent
ET	Exposure Time	✓			
ET	Fixations & Dwell Time	✓			
ET	Pupillometry		✓		
HRV	Inter-beat Variability	✓	✓		
HRV	LF		✓		
HRV	HF	✓			
EDA	SCL (mV)		✓		
EDA	SCROnset (µS)		✓		
PPA	Hippocampus			✓	
PPA	dlPFC			✓	
PPA	PPA			✓	
PPA	vSTR				✓
PPA	vmPFC				✓

Results

Phase 1: Moment-to-Moment Exposure & Interaction with Ads

Screening and Self-Report: An Incomplete Perspective

Sixty-four participants were recruited for Phase 1 of the study. Due to errors in data collection and noncompliance during the experimental procedure, eight participants were removed from the overall analysis. Thus, the final analysis for Phase 1 focused on a core set of 56 participants. Demographically, most participants have at least two years of college experience (e.g., Associate degree) or higher and are employed. Additionally, most participants reported in a prescreening questionnaire that they check their postal mail every day and electronic mail multiple times a day, prefer communications via electronic mail, and find electronic mailers to be more relevant based on a pre-screening questionnaire[5].

In the self-reported measures, we found no significant differences in preferences and attitudes for the ads and their contents when comparing between the physical and digital counterparts of the same ad[6]. For baseline measures (pre-ad exposure), there were no differences for item familiarity, purchase intention, and previous purchase history for the items used in the study. Measures collected post-ad exposure such as item familiarity, purchase intention, ad familiarity, ad relevancy, and ad

5 The participant profile in this study is similar to a larger pre-test we conducted with an online panel (n = 121). Thus, we believe that these prior perceptions of physical and digital communications in this study are representative of the general population and not unique to the sample of this study.

6 This result is similar to a behavioral pre-test that we conducted prior to the main study on an independent sample of 48 people.

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likability also showed no significant differences for the same set of ads as a function of physical or digital exposure.

Looking at the relationship (i.e., correlation) among self-reported measures at baseline (pre ad exposure), participants were more likely to have purchased an item used in this study if they were familiar with it. Post-ad exposure, participants were more likely to purchase an item featured in the ad if they found the ad content more relevant and likable.

Eye Tracking & Biometrics: Dissociation between Attention/Engagement and Affect

To evaluate eye–tracking and biometric results, we aggregated data across the different ads in each format, and performed analysis on the process and physiological data at the block level (e.g., physical or digital block). This was done because the data at the ad-level was extremely noisy due to the variability in exposure times and attitudes across participants.

For eye tracking, we focused primarily on what participants were looking at and processing in their visual field, specifically for the physical or digital ads. The gaze data – captured at high temporal resolution – provided insights into what participants were looking at and the relative duration spent on processing the various components of the advertisements. Therefore, these measures provide insights into the overall attention and engagement with the ad across formats. Furthermore, the levels of dilation of the pupil measured using eye tracking also provide valuable insights into the arousal level during ad exposure.

In general, there were significant differences in the way participants processed advertisements in the physical postcard format and digital e-mail format. Participants tended to spend more time when interacting with physical advertisements and this also translated to a higher number of fixations recorded. However, although participants spent more time with physical ads, they were less focused in their gazes as indicated by a lower proportion of time spent on fixating on the ad. Additionally, participants' eye gazes tended to be more mobile when looking at physical ads (e.g., greater proportion of time spent on saccades). Building upon this result, participants also had a greater proportion of long fixations (>150ms) when looking at digital ads and, on average, spent more time per fixation when processing the ad (dwell time on ad), as well. Longer fixations and greater dwell time are often indicative of greater attention, as longer fixations and greater dwell time represent focused processing as compared to more cursory processing during short fixations.

Based on the aforementioned eye tracking results, participants, on average, were more attentive when looking at digital ads compared to physical ads, even though they were exposed to physical ads much longer. However, greater attention could solely mean greater awareness of the general visual scene, but not necessarily of specific contents in the scene. In order to better quantify specific awareness, or engagement, we looked at the proportion of time participants spent processing the brands and/or products on the ads. Looking at this data, there were no significant differences in the proportion of time spent on the product and/or brand as a function of media. In other words, although there was less attention during physical ad exposure, this did not translate into lesser engagement with the contents featured in the physical ads. It is possible that the extended exposure time for physical ads compensated for the less focused processing and attention.

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From the pupil data recorded, the average pupil size was significantly larger during exposure and interaction with physical ads relative to digital ads. Physiologically, pupil dilation occurs at a heightened stage of arousal. Thus, based on pupil data, we contend that there is a greater level of arousal, on average, during ad exposure in the physical environment relative to the digital environment.

Therefore, the results from eye-tracking data suggest dissociation between greater arousal during interaction with physical ads, and greater attention, but not necessarily engagement, during interaction with digital ads. However, in order to substantiate the basic dissociation between arousal and attention (engagement aside), we next analyzed the data from heart rate variability (HRV) and skin conductance activity (EDA).

For heart rate variability, we considered measures along both the time- and frequency-domains. Looking at the time-domain analysis of HRV, we found that participants had more variability when they interacted with physical ads. Specifically, participants had faster heart rate and greater variability in their inter-beat intervals during interaction with physical ads relative to digital ones. Upon examination of the frequency-domain analysis of HRV, there was significantly greater parasympathetic tone (HF) when participants were looking at digital ads. This is an indication that participants had greater heart rate deceleration, indicative of a more relaxed and calm state and increased attention when interacting with digital ads. The greater heart rate deceleration difference is further supported by a lower average heart rate during interaction with digital ads in the time-domain analysis (greater heart rate deceleration can lead to lower heart rate). Additionally, although only trending towards significance, we found greater sympathetic tone (LF) when participants are looking at physical ads. Greater sympathetic tone is indicative of greater level of arousal and greater heart rate acceleration, which is supported by the faster heart rate during interaction with physical ads.

As aforementioned, skin conductance activity (EDA) provides a more reliable measure of sympathetic nervous system response than heart rate variability could. Thus, the arousal differences observed in eye tracking and HRV results can be addressed more reliably with skin conductance by examining both the tonic and phasic level of electrodermal activity. At tonic level of EDA, participants had higher levels of skin conductivity (SCL), on average, before looking at physical versus digital ads. Additionally, this difference was also noted in the skin conductance response at onset. In other words, tonic and phasic skin conductivity were higher at the anticipation of looking at physical ads relative to digital ads. At the phasic level of EDA during the exposure period, there was significantly greater fluctuation, or the amplitude of skin conductance responses (SCR), in the tonic signal across participants during physical ad exposure. However, there were no differences in the percent of valid SCRs during interaction with physical or digital ads. In other words, there were similar amounts of valid skin conductance activity in both exposure contexts; however, there was a greater level of arousal when participants were interacting with an advertisement in the physical format compared to the digital format. These results provide strong converging evidence for the arousal differences found in both the eye tracking and HRV analyses above.

Phase 2: Neural Differences in Context Memory & Preferences

Of the 64 participants who completed Phase 1 of the study, 57 were enrolled in Phase 2. However, only 48 participants completed Phase 2 (9 participants did not show up to their scheduled scanning sessions because of inclement weather or other personal reasons). Of the 48 participants, an additional 9 participants were removed from final analysis due to gross movement during the scans or task noncompliance within the scanner. The results from the remaining 39 participants are reported below[7].

Of the data collected for Phase 2, memory retrieval for the items (ads) and sources were assessed. Specifically, we sought to understand whether or not item and source memory differ[8] and which neural mechanisms are driving such effects. Not surprisingly, all participants were able to correctly identify *old* and *new* ads with high confidence. Most participants were not able to correctly identify the sources for all ads they identified as *old*. However, participants were significantly more confident when they correctly identified the source of an *old* ad if the given ad was experienced in the physical postcard context compared to digital e-mail context. Additionally, participants were significantly quicker in correctly identifying an ad's exposure source, and with high confidence, when the ad was originally exposed in the physical context compared to similar high confidence and correct responses for digital ads. There were no significant differences for low confidence responses that correctly identified an ad's exposure source.

In the neural data, there was increased activation, at a threshold of $p_{uncorr} < 0.001$, in the left hippocampal and parahippocampal place area (PPA) regions for physical ad retrieval compared to digital ads. No dorsolateral prefrontal cortex activity differences were recorded. Greater PPA activity for physical ads at retrieval supports prior literature that examines this region's role in encoding contextual information (Epstein et al., 1998; Epstein et al., 2007; Epstein and Ward, 2009; Park and Chung, 2009). We contend that participants retrieved a much richer context about the ads when they were previously presented in the physical format relative to digital format. This is also consistent with better source memory for physical ads reported above.

Looking at the preferences via willingness to pay (WTP), there were no differences for products that were previously advertised in a physical or digital ad context. Additionally, there were no differences in the amount of time participants took to provide their bids inside the scanner. Yet, at the neural level, we found differences when participants were providing their bids (willingness to pay) for items that were advertised in physical relative to digital ad context. In this analysis, participant's neural responses are modulated by the participant's different WTP's for the various items. We found greater vmPFC activity across all items, regardless of exposure medium, when neural activity was modulated with individual WTPs, consistent with several previous studies (Plassmann, O'Doherty, & Rangel, 2007; Plassmann et al. 2008). However, there were no differences in the vmPFC activation between physical and digital conditions. Looking at the difference between sets of items (physical – digital),

7 Please note that the usual sample size for an fMRI study is between 25 – 30 participants.

8 In an independent sample of 48 participants, we found that there was no significant difference in memory retrieval of physical or digital ads (item memory). In fact, most participants were able to recognize most ads they were exposed to as *old* and the foils (new ads) as *new*. However, we found a significant difference in the source memory for the ads participants have seen. In fact, for ads participants were exposed to in the physical condition, participants were more likely to be correct in their assessment of the source, as well as more confident in their responses.

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there was stronger right vSTR activity ($p<0.001$ uncorrected) for items advertised in the physical context relative to the same items advertised in the digital context. Given the role of this region in reward processing and measuring motivation and desirability, we argue that the increased modulation of this region for physical exposure might indicate an increased desirability for the items featured in these ads. The lack of corresponding differences in self-reported WTP may reflect the strength of inherent preferences due to the familiarity with majority of items featured in the study. This needs to be explored further in future studies using more novel products.

Table 5. Results Summary

	Physical Ads	**Digital Ads**
Attention/Engagement	Similar level of engagement as digital ads	Greater attention
Affect	Greater arousal	
Memory	Greater and more confident responses in source memory, including faster retrieval time of such source memory	Similar item memory accuracy as physical ads
Desirability	Greater subjective valuation and desirability for items advertised in physical ads	No differences in revealed preferences

Discussions

To the best of our knowledge, this was the first study to look at the effectiveness of cross-media marketing using neurophysiological methods. Crucially, the robustness of the experimental design allows us to make predictions about the effectiveness of different methods during various stages of the buying process, beyond those possible from traditional methods. Specifically, we focused on the three main stages of the buying process:

1. Information search and processing (e.g., looking at advertisement contents and engaging with advertising content)
2. Retrieval of gathered information (e.g., recall/recognition) during the product evaluation stage
3. And ultimately the action (e.g., response rate, purchase intent, or willingness to pay)

The main focus of our study was on stage 1 of the buying process – the information search and processing. We used biometrics and eye tracking to study the relative levels of arousal, engagement and information processing when participants were exposed to the materials in physical and digital formats. We studied retrieval of gathered information by asking participants to return for an fMRI session a week later and make decisions about the novelty of the advertisements provided on the screen. Crucially, in the same session, we also asked participants to indicate whether or not they would purchase the products featured on the screen and how much they would be willing to pay for these products in an incentive-compatible manner. Therefore, the second fMRI session sought to address the effectiveness of the different campaigns for stages 2 and 3 of the buying process.

The self-report data in our study showed little differences in consumer preferences and attitudes when looking at advertisements through the physical or digital context. For most marketing research companies, this would suggest that they should go with the medium that is convenient and cost efficient. However, the use of converging evidence across multiple neurophysiological methods like eye tracking, heart rate, skin conductance, and fMRI provides a more nuanced story about the effectiveness of physical and digital advertisements, with clear implications for marketers along the buying process, as outlined below.

Differences in Information Processing during Ad Exposure & Interaction

In general, participants spent much longer when interacting with and exploring physical ads compared to digital ads, while they were more focused and systematic in the processing of the latter. The HRV results confirmed the assessment of greater attention for digital ads versus physical ads during ad exposure. However, greater attention and systematic processing associated with viewing digital ads did not necessarily translate to greater engagement or deeper processing. On the other hand, the longer exposure times for physical ads allowed participants to process as much information as they did for digital ads. One practical implication that can be drawn from this finding suggests that digital ads are more efficient at delivering marketing contents to consumers. However, based on the complete results of this study, we argue that the decision for the correct media to deliver marketing contents to consumers is more complex.

Crucially, during the same exposure period, we found that physical ads were associated with greater levels of arousal when participants interacted with these materials. This was confirmed with converging data across three different methodologies. Physical ads were associated with increased pupil dilation, greater heart rate acceleration and increased skin conductance levels, each of which provides independent validation about increased arousal for physical ads.

We believe that the structured and familiar nature of the environments in which participants are exposed to the stimuli may explain the greater attention for digital over physical media, discussed above. In general, the digital environment is more structured compared to the physical environment. This is true whether participants look at the digital ads on a computer monitor or on a tablet. Based on the demographics and self-reported survey responses of the participants, they are not unfamiliar with receiving ads through e-mail and the format in which they receive these ads. Thus, by telling participants they need to evaluate every ad in a given e-mail box, they are provided more structure to do so in the digital environment. This structure allows participants to be more directed in their task of evaluating different advertisements embedded into different e-mail offers, all listed inside an inbox. Additionally, in the digital environment, participants know what to expect from the ads based on the sender of the e-mail (in this case the brand) and the contents of the e-mail based on the subject line (in this case the name of the product). This reduces the overall exposure time.

However, in the physical environment, which is more true to the everyday environment, there is less structure as participants must shuffle though the different advertisements without knowing much about the subsequent ads during the task. Moreover, the physical environment is dynamic and not bounded by any visual window such as a screen. Thus, in the physical environment, participants are not inherently restrained in their visual field as they are processing any given ad.

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Thus, their gazes can be less direct and more mobile as they evaluate the ads in a more visually noisy environment.

In summary, we demonstrate an interesting dissociation between arousal and attention when participants are first exposed to the ads in the physical and digital context. Specifically, we find that physical ads are associated with greater arousal, while digital ads are associated with more systematic processing and greater attention. But what are the implications of these findings for the later, and more crucial, stages of the buying process? Are participants more likely to remember information presented in a particular format? Does the format in which the advertisement is initially presented impact the likelihood of purchasing the product featured in the ad? We addressed these questions by asking participants to return for a second session a week later.

Differential Effect of Advertising Media on Memory and Preferences

We measured each participant's memory for the various advertising materials approximately a week after initial exposure. First, the increased attention and systematic processing when interacting with ads in the digital context during initial exposure did not lead to superior memory performance. However, participants in general were extremely accurate in retrieving ads across both formats (accuracy > 95%). Therefore, we looked at their ability to retrieve the context surrounding the initial ad exposure by asking participants to simply state whether they were exposed to the ad in physical or digital ad. Strikingly, we found that participants were more confident about the source when they had seen an ad in the physical format, demonstrating that the clutter and decreased attention in the physical environment did not adversely affect the participants' overall processing of physical ads. Instead, we speculate that the increased arousal promoted better processing and consolidation at the exposure phase, which could account for the increased confidence about the context. This is validated by the fact that participants were faster in retrieving information that was previously presented in physical format.

Our findings were also nicely validated by the neural data. We found greater activation in the hippocampal and parahippocampal areas for physical compared to digital ads. The hippocampus has been associated with memory formation and retrieval across several studies. The parahipppcampal region has been strongly associated with processing of scenes and contextual information in previous studies. Greater activation of this region, at retrieval, suggests that participants managed to remember a broader context about the stimuli in the physical condition compared to the digital format. This could have crucial implications for marketers, if true. For instance, participants may be more likely to remember promotions and price discounts when they are exposed to such information in a physical format compared to digital format. This needs to be independently verified in future studies.

Finally, self-report data suggested that participants did not show any differences in the purchase intent or willingness to pay for the same items they saw advertised in the physical or digital contexts. This lack of difference may not be surprising given the nature of items featured in this study. Participants were familiar with most of these items and hence had strong preferences for these items, and their price points were unlikely to change by the subtle exposure to advertising stimuli in different contexts. However, at the neural level, we found greater activation in the ventral striatum for items advertised in physical context relative to digital context. This region has been strongly associated with reward processing and desirability, and was the strongest predictor of real-world advertising sales in a previous study. Therefore, this could indicate that physical ads could have increased the desirability for these items, although such differences were not captured in the self-reported purchase intent or willingness to pay measures. Future studies need to explore this further through the use of more natural shopping contexts and novel products, where participants are less likely to have strong prior preferences.

Context Matters

In an age where digital communication is becoming more accessible and cost efficient, there begs a question of the importance of physical mailers when marketing executives are making decisions about cross-media campaigns. For a marketing research company, the assessment of the impact and efficacy between physical and digital ads often stops at the self-reported levels. The dangers of such conclusions are highlighted by the fact that there were no real differences in advertising with physical or digital ads in our study when using participants' revealed attitudes and self-reported preferences for the advertised contents. However, going beyond self-reported measures, we find crucial differences between these formats that could have tremendous implications for marketers when deciding on the type of media to use for their advertisements.

Appendix A: Analyses & Key Measures

Traditional Self Reports

Screening Questions

How often do you check your mail box?
How often do you check your e-mail?
How often are you exposed to printed advertisements?
How often are you exposed to digital advertisements?
Do you prefer communication by postal mail or e-mail?
Do you prefer to receive your bills through postal mail or e-mail?
On average, how relevant are the advertisement contents you receive through postal mail?
On average, how relevant are the advertisement contents you receive through e-mail?
On average, when do you discard the advertisements you receive through postal mail?
On average, when do you delete your e-mails containing advertisements?

Self-Reported Measures

Item Familiarity Pre	Familiarity with advertised product/services/restaurant prior to ad exposure. Items are presented outside the contexts of the advertisements, e.g., product shot.
Item Familiarity Post	Familiarity with advertised product/services/restaurant after ad exposure. Items are presented within contexts of the advertisements.
Purchase Intent Pre	Item purchase intent prior to ad exposure.
Purchase Intent Post	Item purchase intent post ad exposure.
Purchase Intent Delta	Difference in purchase intentions (post – pre).
Purchase Intent PAR Corrected	Difference in purchase intentions (post – pre) corrected for baseline biases.
Previous Purchase	Previous purchase/consumption of items.
Ad Relevancy	Advertisement relevancy (e.g., contents).
Ad Familiarity	Familiarity of advertisement.
Ad Likability	Likability of advertisement.

Eye Tracking

Raw eye tracking data was processed using Tobii Technology's IV-T Fixation filter built into Tobii Studio Pro. Using the IV-T filter, raw eye tracking moments were classified as fixations, saccades, or eye blinks. Processed eye tracking data was exported and analyzed further in MATLAB. Only data with greater than 60% validity[9] were included in the final analyses.

Processed eye tracking data can be analyzed along two different domains. The first domain concerns the temporal aspect of the data, such as exposure time, and the amount of processing

9 Valid data are defined as data where both eyes are successfully identified by the eye tracker. Eye tracking data can be invalid if there was a bad calibration step or other factors such as participants blinking too much.

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recorded during the established epoch, such as the number of fixations and their localities. The second domain concerns with the physiological responses of the pupils, called pupillometry. Pupil dilations are elicited by external stimuli and are often used as an index of overall arousal. We expand further on the first domain below.

Focusing at the temporal domain of eye tracking data, we report the total exposure time for each advertisement participants see (RT). We further parcellated the total exposure time into time spent on fixations (RTFix)and time spent on exploration (RTSacc). In Phase 1, in which eye tracking data was collected, participants were allowed to spend as much time as they wished on any given ad for both physical and digital ads. In order to control for individual differences in this situation, we can normalize the parcellated exposure times by the overall exposure time for each participant to get the proportion of time spent on fixations (pRTFix) and the proportion of time spent on exploring (pRTSacc). To further subdivide RTFix, we created three broad areas of interests (AOI), defined as the ad within the testing environment, the product, and the brand. The last two areas of interests are a subset of first. Using these AOIs, we identified overall time spent looking at the ad (RTAd), the product (RTProd), and the brand (RTBrand). Again, these times are normalized within each participant by the overall time spent on the ad to get proportion of time spent on the product (pRTProd) and proportion of time spent on the brand (pRTBrand).

In order to characterize what participants were processing, we identified the number of fixations that were recorded during overall exposure time (NFix) and their locations. Using the AOI on the ad identified above, we report the number of fixations on the ad (NFixAd) and classified whether or not such fixations are long fixations (NFixL) or short fixations (NFixS)[10]. Similar to exposure time, we normalized fixation data for each participant to assess the proportion of fixations spent on the ad (pNFixAd), the proportion of long fixations on ad (pNFixL), and the proportion of short fixations on ad (pNFixS). Combining exposure time and fixation data, we also provide the average time spent per fixation on the ad (DTAd), on the product (DTProd), and on the brand (DTBrand).

Eye Tracking Measures

RT (sec)	Total exposure time.
RTFix (sec)	Amount of time spent on fixation.
RTSacc (sec)	Amount of time spent on exploring (saccades).
RTAd (sec)	Amount of time spent on ad.
RTProd (sec)	Amount of time spent on product.
RTBrand (sec)	Amount of time spent on brand.
pRTFix	Proportion of time spent on fixation (RTFix/RT).
pRTSacc	Proportion of time spent on exploring (RTSacc/RT).
pRTProd	Proportion of time spent on product (RTProd/RTAd).
pRTBrand	Proportion of time spent on brand (RTBrand/RTAd).
NFix	Number of fixations during total exposure time.

10 Long fixations are defined as any fixation that occurs with durations greater than 150 milliseconds (ms). Short fixations are defined as any fixation that occur with maximum duration of 150 ms. Longer fixations are indicative of greater processing. Shorter fixations are indicative of greater rapid, superficial processing of the environment.

NFixAd	Number of fixations on ad during total exposure time.
NFixL	Number of long fixations on ad (NFixL + NFixS = NFixAd).
NFixS	Number of short fixations on ad (NFixL + NFixS = NFixAd).
pNFixAd	Proportion of fixations on ad (NFixAd/NFix).
pNFixL	Proportion of long fixations on ad (NFixL/NFixAd).
pNFixS	Proportion of short fixations on ad (NFixS/NFixAd).
DTAd (msec)	Average time spent per fixation on ad.
DTProd (msec)	Average time spent per fixation product.
DTBrand (msec)	Average time spent per fixation brand.
Pupil	Average pupil size from both eyes.

Heart Rate Variability (HRV)
Raw heart rate data was processed using BIOPAC's Acqknowledge 4.2 and analyzed further using Kubios HRV software. Heart rate variability (HRV) analysis looks at the beat-to-beat heart rhythms, which can be captured by quantifying the electrical activity of the heart. Heart rate is controlled by two antagonistic branches of the autonomic nervous system, the sympathetic nervous system (SNS, fight-or-flight system) and the parasympathetic nervous system (PNS, rest-and-digest system). When measuring heart rate, we are interested in capturing moments when heart rate is accelerating or when it is decelerating. By the nature of the physiological systems directly affecting heart rate, heart rate acceleration is controlled by the SNS and provides an independent measure of arousal. Increased heart rate deceleration is controlled by the PNS and indicates an increased ability to focus on the external stimulus, and hence provides an independent measure of attention.

On average, the human adult heart beats between 60-100 beats per minute (BPM) at rest. However, looking at the average heart rate alone does not provide us with information we need regarding the physiological responses participants have when they interact with advertisements in the digital and physical formats. These physiological responses are those described above with respect to the SNS and PNS control of heart rate. In order to do this, we focus on how the participant's heart rate varies over time during the experiment. Heart rate variability analysis, thus, focuses on studying the variations between inter-beat (RR) intervals, or RR-I. In the diagram below, we show a typical EKG recording. For our purpose, we defined the RR-I as the interval between successive heartbeats as indicated by the R-peak of the QRS complex. Classifying the inter-beat intervals using the R-peak of the QRS complex is more stable than doing so using the P- or T-peak due to noise susceptibility in these peak measures. Below is also a depiction of the aforementioned peaks on an illustrated EKG recording.

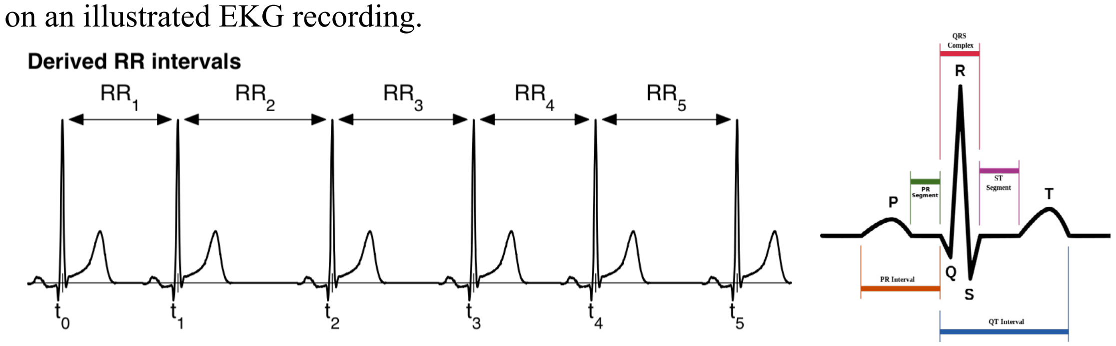

Figure A1. Left depicts how heartbeats are determined using the R-peaks in the QRS complex of a heartbeat (right).

To assess HRV, we employ two commonly used analyses in the HRV literature. The first analysis is the time-domain analysis of HRV, which allows us to study the temporal features of the variability. In this domain, we can look at the mean inter-beat intervals (mRR-I), variation in inter-beat intervals (sRR-I), mean heart rate (mHR), and the proportion of successive intervals differing more than 50ms (pNN50). To better understand what each of these measures do, remember that we are looking at the interval between successive heartbeats. Typically, heart rate is reported in beats per minute. Using the RR-I (in seconds), we can calculate HR by taking 60/RR-I. Given this information, we show that a greater mRR-I produces a slower HR and a smaller mRR-I produces a faster heart, which are often linked to a higher sense of alertness and arousal, respectively.

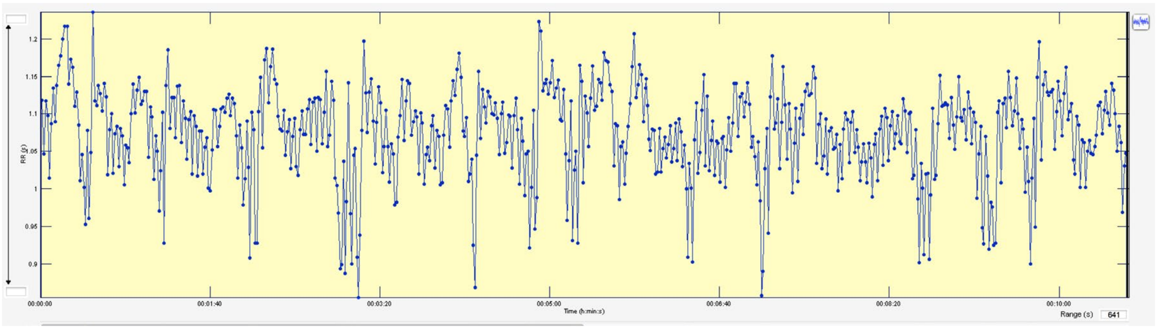

Figure A2. Plot of RR-I's extracted from recorded EKG signal.

Using sRR-I, we can capture the variability between different inter-beat intervals. A larger sRR-I indicates greater heart rate variability and greater parasympathetic tone. The opposite indicates less heart rate variability and greater sympathetic tone. Using pNN50, we can study the proportions of RR-I's that are greater than 50ms from their adjacent neighbors. This measure can be used as another proxy of variability. Like the sRR-I measure, pNN50 does not indicate how each RR-I differs temporally. However, it does indicate what proportions of adjacent RR-I's that differ more than the prescribed 50ms threshold.

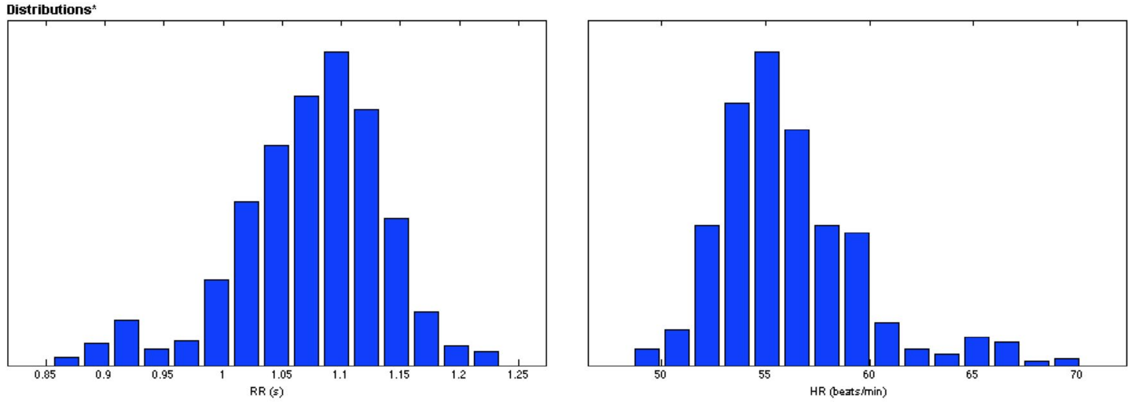

Figure A3. Temporal-domain analysis of heart rate variability. The left plot shows a histogram of RR-I's and the right plot shows the corresponding histogram of HR.

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In order to better characterize the differences we see in in the time-domain analyses, we must also look at the frequency-domain of HRV. Frequency-domain analyses allow us to study the proportion of sympathetic and parasympathetic control on HRV. In this domain, sympathetic tone is linked to signals within the low frequency (LF) band between 0.04 to 0.15 Hz, while parasympathetic tone is linked to signals within the high frequency (HF) band between 0.15 to 0.4 Hz. Using signal-processing techniques, such as power analysis, we can analyze the different contribution of each band on the overall heart rate signal. It must be noted that LF has also been shown to indicate some parasympathetic tone. However, in this study, we define LF as a proxy of sympathetic tone.

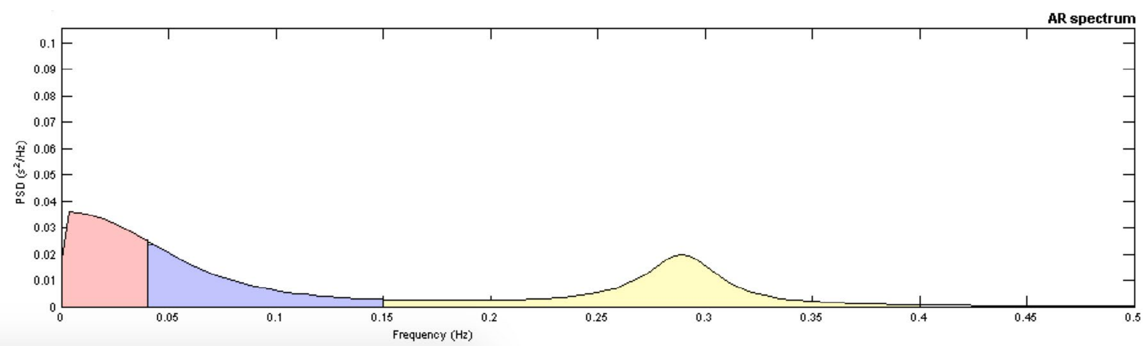

Figure A4. Frequency-domain analysis looking at contribution of LF (purple) and HF (yellow) to overall HRV signal.

Heart Rate Variability Measures

mRR-I (s)	Mean inter-beat interval.
sRR-I	Standard deviation of inter-beat interval.
mHR (bpm)	Mean heart rate.
pNN50	Percentage of RR-Is differing more than 50ms from adjacent neighbor.
LF	Low frequency band of HRV defined between 0.04 – 0.15Hz. A contested measure of sympathetic and parasympathetic tone.
HF	High frequency band of HRV defined between 0.15 – 0.4Hz. A measure of parasympathetic tone.

Electrodermal Activity (EDA)

Raw EDA signal captures the tonic activity of skin conductivity. The most common measure that we can derive from the tonic signal is the skin conductance level (SCL). This is a slow varying signal that describes the overall conductivity of the skin over long epochs of recording. Because of the tonic nature of SCL, this measure is more indicative of general level of arousal and is more susceptible to individual physiological differences.

In order to account for individual differences, we focus our analysis on another measure of EDA. From the tonic skin conductance level, we can identify phasic changes that are referred to as skin conductance response (SCR). Skin conductance responses are short fluctuations in tonic signal that reflect higher-frequency variability of the recorded skin conductivity signal. Unlike SCL, SCR is more discrete and short-lasting, usually lasting several seconds. Additionally, SCR can be directly linked to external stimuli that elicit these responses. In other words, SCR occurs when the skin transiently becomes a better electrical conductor due to increased activity of the eccrine (sweat) glands following exposure to certain external stimulus. In order to measure more targeted level of arousal, such as when participants are evaluating physical or digital ads, we report the mean amplitude, or peak response, of SCR. By measuring the SCR at onset of a physical or digital block, we can compare the overall level of arousal by subtracting this measure from the amplitude measure.

By measuring SCR's, we are measuring changes in skin conductance due to external stimuli exposure. Such changes are regulated by the SNS branch and thus are indicative of participant's arousal level during stimulus exposure. Due to the nature of physiological responses, SCR's are only indicative of arousal during stimulus exposure. They cannot reliably indicate emotional valence.

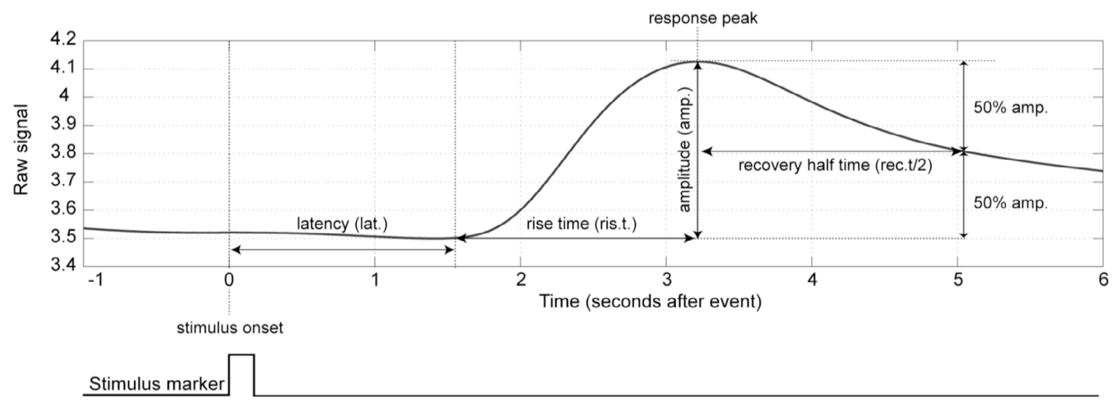

Figure A5. Plot of a typical skin conductance response as adapted from Figner & Murphy chapter on using skin conductance in judgment and decision making research.

Electrodermal Activity Measures

SCL (mV)	Skin conductance level before exposure to stimuli.
pValidSCR	Percent valid skin conductance responses.
SCROnset (mS)	Skin conductance response at onset of stimuli exposure.
Amplitude (mS)	Response peak of SCR.

Functional Magnetic Resonance Imaging (fMRI)

Functional magnetic resonance imaging, or fMRI, is a non-invasive method that localizes and tracks changes in blood oxygenation during ongoing cognitive tasks (Ogawa et al., 1990). The blood oxygenation level dependent (BOLD) contrast is based on the fact that hemoglobin has different magnetic properties depending on its oxygenation state: oxyhemoglobin is diamagnetic while deoxyhemoglobin is paramagnetic and that paramagnetic substances lead to greater distortion of the surrounding magnetic field. Since neural activity following a specific task utilizes oxygen within specific regions of the brain, the brain vasculature responds by increasing the flow of oxygen-rich blood into the region. This leads to a localized increase in BOLD signal intensity in that region of the brain, which is then measured using high-field magnetic resonance scanners (Huettel, Song, and McCarthy, 2004). Thus, the fMRI provides an indirect and correlative measure, at the macroscopic level, of local brain activity at a very high spatial resolution (about $1mm^3$) and good temporal resolution (about 2-6 seconds).

Using fMRI, we wanted to capture neural activities at time of memory retrieval, such as identifying if an ad was *new* or *old*, and whether an *old* ad was seen in the *physical* or *digital* format. Additionally, we were interested in capturing neural activities during moments when participants were evaluating their willingness to pay (WTP) to receive an item advertised in the stimuli. Participants performed these evaluations knowing that a real exchange would occur at the end of the task that involves them purchasing a randomly chosen item using money they were endowed for participating in the study.

For fMRI, there are two general ways to look at the neural activation. The first is a whole-brain analysis that looks at all parts of the brain and their correlation to the task at hand. The second is to look at targeted regions, called regions of interests (ROI), in which we have *a priori* beliefs on their involvement with the tasks we used based on prior literature. For the latter, we will focus on the hippocampus, parahippocampal place area (PPA), and dorsolateral prefrontal cortex (dlPFC) regions during memory retrieval. We will focus on the ventromedial prefrontal cortex (vmPFC) and ventral striatum (vSTR) regions during willingness to pay task.

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Functional MRI Regions of Interests (ROI)

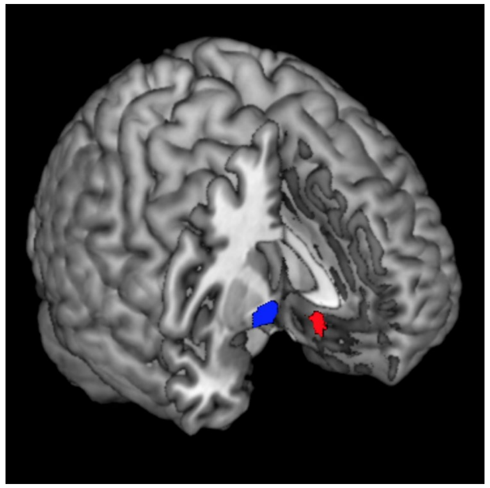

Figure A5. ROI of ventral striatum (blue) and ventromedial prefrontal cortex (red)

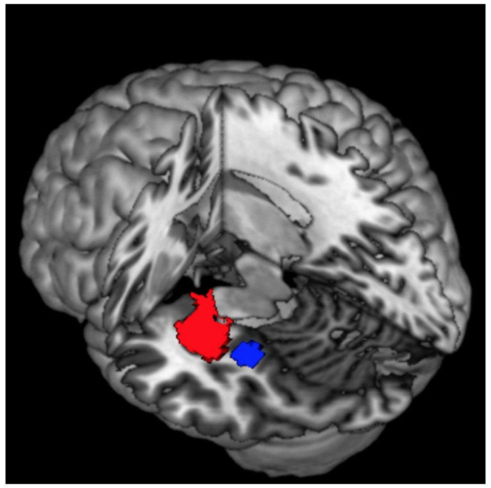

Figure A6. ROI of hippocampus (red) and parahippocampal place area (blue).

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Appendix B: Results Tables

Self-reported Measures

	Set 1		Set 2	
	Physical	Digital	Physical	Digital
Item Familiarity Pre	4.416	4.381	4.128	4.166
Item Familiarity Post	4.644	4.815	4.634	4.653
Purchase Intent Pre	4.186	4.115	3.954	4.181
Purchase Intent Post	3.817	3.977	3.894	3.950
Purchase Intent Delta	-0.370	-0.138	-0.059	-0.231
Purchase Intent PAR Corrected	-0.587	-0.414	-0.479	-0.453
Previous Purchase	2.576	2.413	2.370	2.738
Ad Familiarity	3.214	2.854	2.628	3.278
Ad Relevancy	4.152	4.252	4.134	4.242
Ad Likability	4.554	4.633	4.605	4.785

Eye Tracking

Source	Physical	Digital	P-val
RT (sec)	14.85	11.29	0.00
RTFix (sec)	9.89	8.65	0.01
RTSacc (sec)	2.69	1.46	0.00
RTAd (sec)	9.55	7.02	0.00
RTProd (sec)	1.96	1.40	0.00
RTBrand (sec)	0.68	0.46	0.00
pRTFix	0.68	0.77	0.00
pRTSacc	0.18	0.14	0.00
pRTProd	0.21	0.20	0.42
pRTBrand	0.08	0.07	0.18
NFix	44.20	35.46	0.00
NFixAd	41.97	27.73	0.00
NFixL	25.56	18.73	0.00
NFixS	16.41	9.00	0.00
pNFixAd	0.95	0.78	0.00
pNFixL	0.61	0.66	0.07
pNFixS	0.39	0.34	0.07
DTAd (msec)	228.82	247.89	0.04
DTProd (msec)	227.24	250.30	0.02
DTBrand (msec)	224.38	260.32	0.00
Pupil (mm)	3.60	2.93	0.00

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Heart Rate Variability (HRV)

Source	Physical	Digital	P-val
mRR-I (sec)	0.81	0.83	0.00
sRR-I	0.05	0.05	0.02
mHR (bpm)	77.61	75.44	0.00
LF	40.73	37.64	0.11
HF	25.36	29.82	0.01

Electrodermal Activity (EDA)

Source	Physical	Digital	P-val
SCL (mV)	11.35	10.16	0.00
pValidSCR	0.69	0.64	0.32
SCROnset (µS)	10.60	9.15	0.00
Amplitude (µS)	11.15	9.52	0.00

Source Memory

	$Source_{high\_con}$ [11]		RT_{high_con} (sec)		RT_{low_con} (sec)	
	Physical	Digital	Physical	Digital	Physical	Digital
Mean	0.66	0.55	0.89	1.11	1.47	1.48
SD	0.31	0.29	0.39	0.45	0.46	0.47
P-val	0.03		0.00		0.92	

Willingness to Pay (WTP)

	WTP ($ Amt)		RT (sec)	
	Physical	Digital	Physical	Digital
Mean	20.77	21.09	3.44	3.40
SD	7.20	8.10	0.45	0.43
Min	7.75	7.45	2.43	2.47
Max	37.95	35.65	4.25	4.45

11 $Source_{low\_con}$ can be calculated by taking (1 – $source_{high\_con}$).

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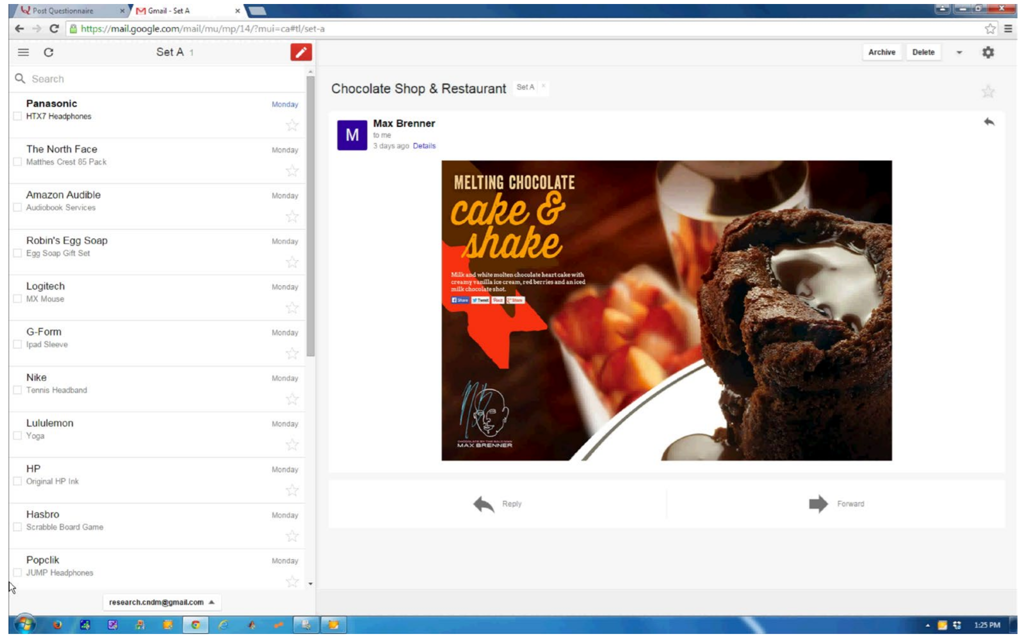
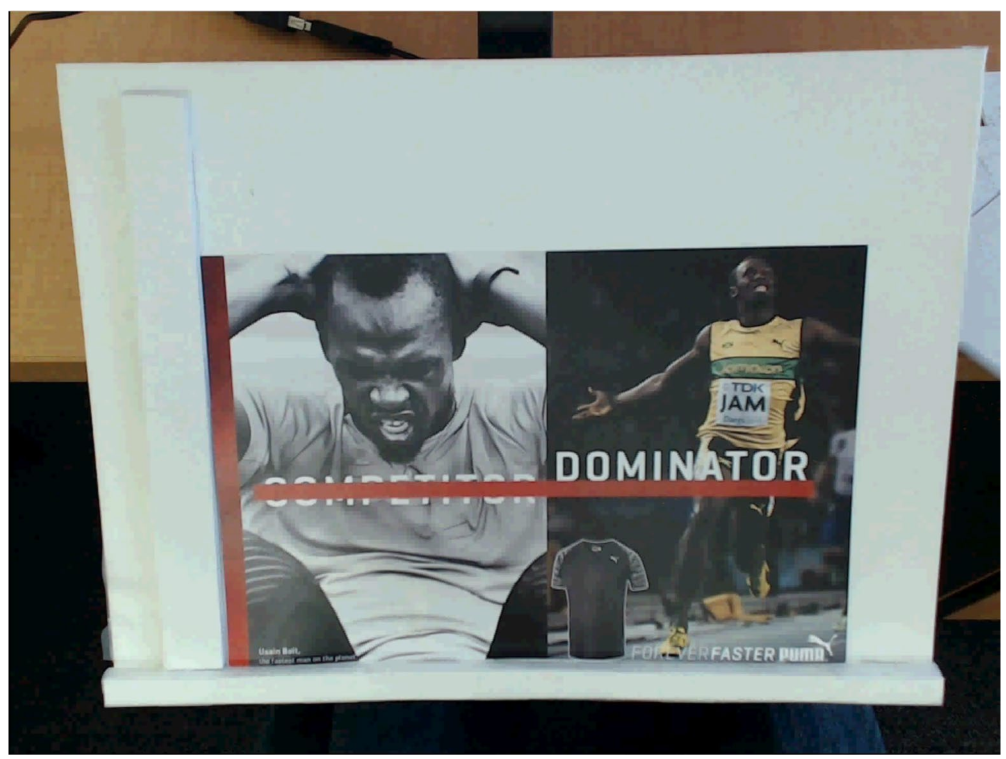
Appendix C: Digital & Physical Ad Environments



Digital ad environment.



Physical ad environment.

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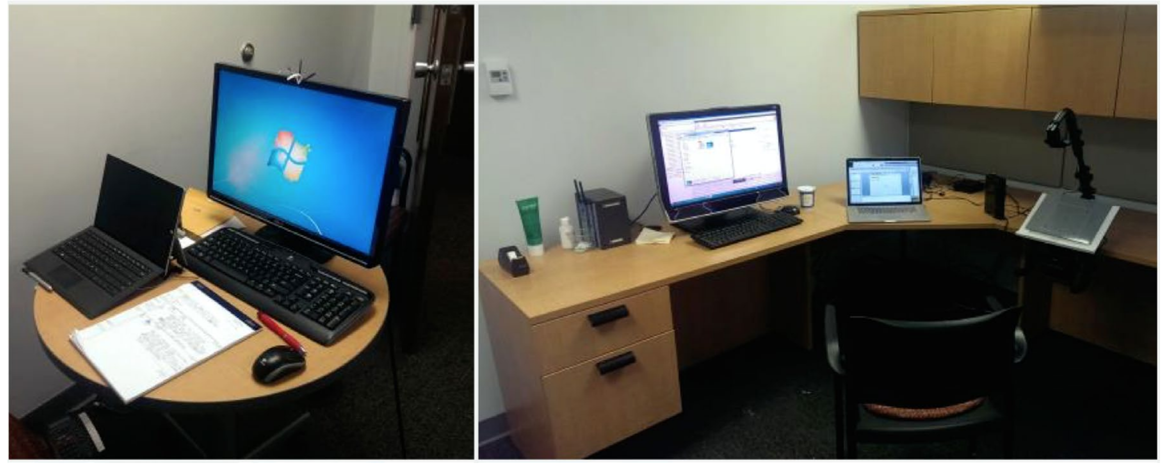
Appendix D: Research Environment



Phase 1 – Eye Tracking & Biometrics

Phase 2 – fMRI

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Appendix E: Example of Area of Interest (AOI)

Appendix F: Pilot Study & Results

Pilot Methodology
Two pilot studies were conducted prior to starting the main study. The first pilot study (Pilot A) was conducted on Amazon Mechanical Turk with a general U.S. population, and the second pilot study (Pilot B) was conducted at Temple University with the university's general sample. Both studies were conducted using Qualtrics online survey platform.

The purpose of Pilot A was to identify and finalize the final advertisement stimuli set, as well as measuring prior perceptions of physical versus digital communication in the general U.S. population. After the final stimuli were selected, Pilot B was conducted to assess attitudes and preferences for the chosen stimuli in the local population, as well as to assess overall level of memory retrieval one week after exposure. The latter was an important exercise to ensure there are no confounding ad effects on memory retrieval.

Pilot A Results
In Pilot A, 121 data sets were collected using Amazon Mechanical Turk, an online, on-demand participant panel. Due to foreign IPs, nine data sets were removed. Results of 112 data sets (67 females) are reported. The population in Pilot A had an age distribution similar to the 2012 census age distribution, which was beneficial for the purposes of Pilot A, because the interest for the pilot was to study the prior perception of communication channels (i.e., physical versus digital), as well as attitudes and preferences for the stimuli utilized in the main study in a general population. Thus, it was important that the age distribution of our respondents was similar to the general US population.

Participants in Pilot A were exposed to 70 marketing stimuli embedded in a questionnaire built using Qualtrics, an online survey platform. From the responses, a subset of 40 advertisements was selected for the main study, which had a robust range of preferences and attitudes in the general population. The results from Pilot A ensured the final 50 advertisement stimuli did not elicit a ceiling or floor effect in preferences and attitudes.

In the general population from Pilot A, participants found digital advertisements to be more relevant and most preferred e-mail communications over physical mail. Furthermore, participants were more likely to purchase an item from an ad if they found the ad content more relevant and more likable.

Pilot B Results
In Pilot B, 48 data sets were collected from the local population at Temple University. Due to noncompliance (e.g., not completing two sessions of the study conducted a week apart), 10 data sets were discarded. The reported data set for Pilot B contains 38 participants (19 females). Unlike Pilot A, participants in Pilot B interacted with the ads similarly to participants in the main study. Half the ads were exposed in the physical postcard format while the other half was exposed in the digital e-mail format. One week after exposure, participants were assessed for their memory of the ads they had seen and the source in which they saw the ads the week prior.

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In the local population, there were no significant differences in self-reported measures of ad familiarity, ad relevancy, ad liking, or purchase intentions as a function of media. In other words, participants in Pilot B did not find an ad to be more familiar, relevant, or likable if it was presented as a digital ad or a physical ad. Likewise, purchase intention for an item did not differ between the same physical or digital ad. Looking at the correlations of the self-reported measures collected, there is a positive relationship between purchase intention and ad relevancy for physical ads. In other words, within the set of physical ads, participants are more likely to buy an advertised item if they found the corresponding advertising content more relevant. This positive relationship between purchase intention and ad relevancy was not found in digital ads.

For the memory measure, there was no significant difference in memory retrieval of physical or digital ads. In fact, most participants were able to recognize most ads they were exposed to as *old* and the foils (new ads) as *new*. However, there is a significant difference in the participants' source memory for the ads they have seen. In fact, for ads participants were exposed to in the physical condition, participants were more likely to be correct in their assessment of the source, as well as more confident in their responses.

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Appendix G: References

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U.S. Postal Service Office of Inspector General
1735 N. Lynn Street
Arlington, VA 22209

Telephone: 703-248-2100
www.uspsoig.gov

For media inquiries, contact Agapi Doulaveris
Telephone: 703-248-2286
adoulaveris@uspsoig.gov