

In-Store Advertising with Digital Signage

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Abstract

Digital signage at the point of sale is emerging as a significant revenue source for retailers and a growing advertising platform for manufacturing brands. Yet, empirical research on its effectiveness remains limited. This study leverages a novel technology and field experimental data spanning 237 advertising campaigns and 30 million shoppers to fill this gap. The authors find that digital signage increases the likelihood of purchasing featured products by 8.1%. This effect is amplified for hedonic, novel, and low-priced products, as well as for popular brands. It is also stronger on weekends, later in the day, during favorable weather, in crowded stores, for emotional advertising messages, and in the absence of concurrent promotional cues. The impact of digital signage further increases when it is placed near the advertised product. Unlike price promotions, digital signage does not affect spending for those who purchase the products. Notably, exposure to digital signage also boosts sales of other products from the same brand and within the same category, without causing purchase acceleration, indicating that it drives incremental consumption. These findings offer new insights into the efficacy of in-store advertising with digital signage and provide actionable guidance for optimizing its use.

Keywords

digital signage, retail media, advertising effectiveness, point of sale, field experiments

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Advertising at the physical point of sale (POS) promises enormous reach to the brands that use it and constitutes a highly relevant revenue stream for retailers (Brodherson et al. 2022; Zhu, Cohen, and Ray 2021). By selling their advertising space, retailers achieve profit margins of up to 90% (Wiener et al. 2022), compared with an average gross profit margin of around 3% (Repko 2023; Wilson 2023), leading to predictions that this revenue stream will account for \$45.3 billion by 2030 (Boidman 2023). For example, Walmart takes advantage of 204 million weekly customer visits to its stores and delivers advertising on an estimated 170,000 digital in-store screens across the United States (Walmart 2023).

Yet even as digital signage at the POS grows more popular, its effectiveness for the manufacturing brands that pay to appear on it is uncertain, and several limitations regarding its accountability remain. Specifically, does digital signage at the POS really increase purchases of featured products? And how strong is this effect across varying conditions? Determining whether online ads are responsible for conversions is already complex (Li and Kannan 2014); establishing causal measures of advertising effectiveness at the POS is even more challenging

because physical shoppers do not leave a trail of their behavior (as online shoppers do). This blurriness may help explain why research on digital signage is scarce to date.

To investigate the effectiveness of digital signage at the POS, it is necessary to isolate its effect from the influence of other marketing stimuli, both outside and inside the store (Iyer et al. 2020). Therefore, we adopt a novel method with the cooperation of a provider company that operates digital signage systems and can match customers' exposure to certain ads with their individual shopping receipts. With this methodology, we effectively rule out shopper-related influences through randomization of participants; we also can exclude the effects of other marketing stimuli by keeping them constant (e.g., same store, same time)

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Figure 1. Examples of Digital Signage at the Point of Sale.

or controlling for their potential effects (e.g., price discounts). Specifically, we analyze the impact of in-store video ads on digital signage using shopping cart radio-frequency identification (RFID) data from 237 field experiments with a total of 30 million shoppers between 2018 and 2022.

Given the importance of digital signage at the POS for both manufacturing brands and retailers, it is critical to understand the factors driving its effectiveness. Although prior research has examined a few contingencies of digital signage, we present a more comprehensive framework that incorporates the role of multiple product-, timing-, and campaign-related factors. Our results indicate that exposure to in-store video ads on digital signage increases the purchase probability of these featured products on average by 8.1%. The increase in purchase probability is influenced by different moderators. In-store ads were more effective for hedonic, novel, and low-priced products and for popular brands, on weekends, later in the day, with better weather, in crowded stores, for emotional messages, and without promotional signals. Moreover, placing digital signage closer to the featured product increases its effect. Exposure to digital signage also increases purchases of other products of the same brand and in the overall category but does not lead to purchase acceleration. Therefore, featuring products on digital signage leads to increased consumption. However, unlike price promotions, digital signage does not affect spending by shoppers who purchase the products.

With these findings, we make several novel contributions. First, we are the first to use extensive field data to study the effectiveness of digital signage for the manufacturing brands that pay for the ads and provide high-margin revenue streams for retailers. With our analysis of 237 campaigns, we can specify which products and campaigns are better suited for digital signage. Similar approaches inform recommendations for other advertising channels (e.g., Bart, Stephen, and Sarvary 2014) but not retail media at the POS yet. Second,

advertising effects tend to be small and advertising field experiments are often statistically underpowered (Lewis and Rao 2015), but by pooling data from multiple campaigns, we can ensure sufficient power to detect digital signage effects and simultaneously account for existing and previously overlooked moderators. Third, we test the theoretical assumptions of the two-step process of attention and appraisal from Inman, Winer, and Ferraro (2009) with a new, distinctive technology that stimulates shoppers' attention at the POS. Consequently, we establish several new empirical generalizations and show that several moderators behave differently in our large study than what prior research on digital signage has demonstrated in studies with smaller samples.

Our findings aid marketers interested in digital signage on three main fronts. First, depending on their situation, manufacturing brands can better predict whether digital signage is likely to pay off for them (e.g., for which products). Second, once they have decided to invest in digital signage, these brands can use our findings to determine when they should run which specific campaign to maximize its effectiveness. Third, retailers can use our results to determine how much they charge brand manufacturers for in-store advertising with digital signage and to develop their pricing and price optimization models.

Background

Digital Signage and Shoppers' Attention

The digital signage format in this study relies on video screens located above main aisles in the store (see Figure 1). These screens play audiovisual content controlled by a central computer server and have an attention-drawing impact on customers due to their vividness, defined as the ability of a technology to produce a sensorial rich experience (Nisbett and Ross 1980). Even if it might be used in some cases to enhance the in-store environment

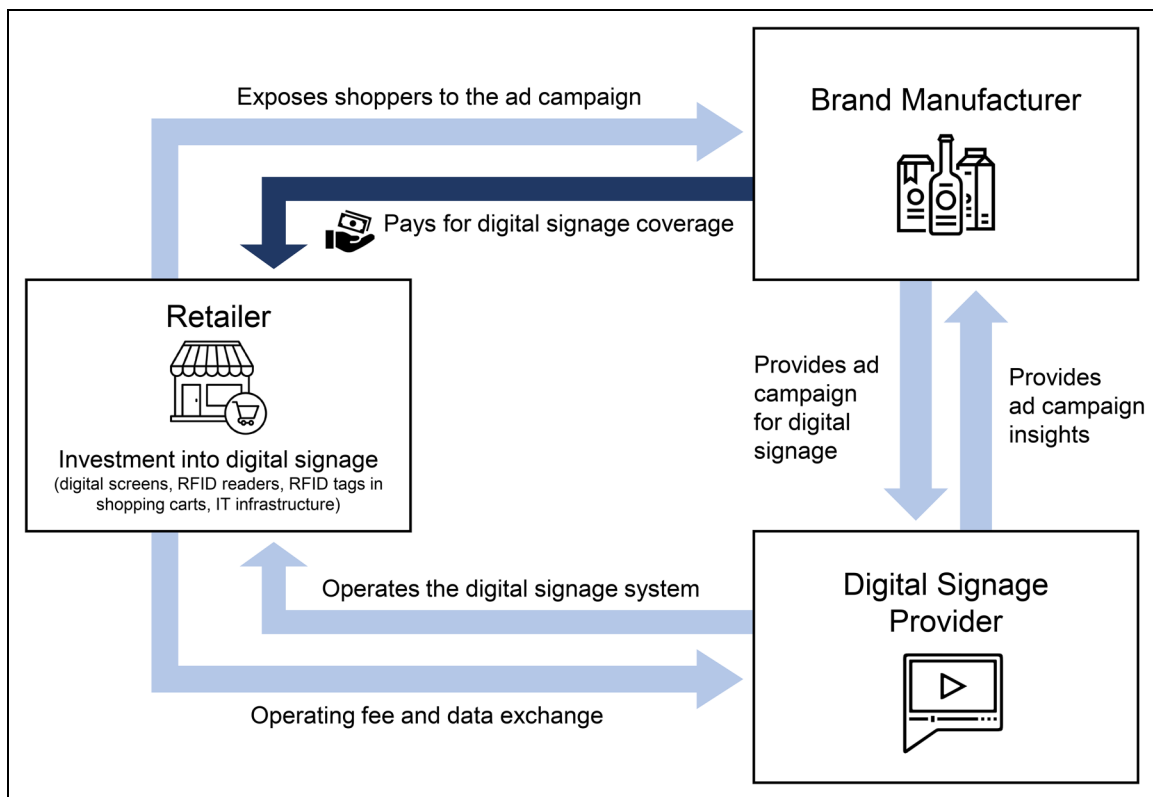


Figure 2. The Digital Signage Business Model.

Notes: The dark payment path is responsible for profit margins of up to 90% (Brodherson et al. 2022; Wiener et al. 2022), compared with an average gross profit margin of around 3% for most retailers (Repko 2023; Wilson 2023).

(Dennis et al. 2010), digital signage mostly serves to promote products to customers (Nanni and Ordanini 2024). Thus, digital signage represents a “reason-to-buy” instrument, designed to motivate consumers to purchase a product by communicating certain brand attributes or relevant brand information (Johnen and Schnittka 2020). The proximity of digital signage to products on the shelf enables manufacturing brands to reach shoppers at a highly relevant moment in their purchase decision process, such that it might evoke an inspiration impulse.

Compared with other in-store advertising instruments, such as nondigital signage or traditional endcaps, digital signage has unique attention-grabbing features that limit the applicability of prior findings. First, digital signage is located in highly frequented aisles in a visual area that captures a lot of attention (Chandon et al. 2009). Shoppers who traverse the aisles in a typical shopping trip pattern with a shopping cart are exposed to its screen for approximately 5–15 seconds (according to the cooperating retailer). Second, the dynamic content on the screens is activated as the shopper’s cart approaches the screen, which triggers their attention because the content starts playing only then, rather than repeating endlessly (Khachatryan et al. 2018). Third, the featured videos elicit focal attention with their moving elements (Greenwald and Leavitt 1984). Fourth, directed audio amplifies the effects of the visual elements (Schweiger et al. 2023). These four features clearly differentiate digital signage from other in-store advertising instruments that are located less

prominently, provide consistent content on an ongoing basis, feature only static elements, and do not feature audio.

The Digital Signage Business Model

While some retailers use digital signage to promote more purchases (Roggeveen, Nordfält, and Grewal 2016), most retailers realize that retail media can be more profitable if they sell this advertising space to manufacturing brands, offering a new, important revenue stream (Brodherson et al. 2022; Wiener et al. 2022). Retailers as varied as Dick’s Sporting Goods, Home Depot, Instacart, Lowe’s, Kroger, Macy’s, Target, Ulta, and Walmart own and operate retail media platforms. In 2023, Walmart earned \$3.4 billion from retail advertising, and Target and Instacart each earned more than \$1 billion (Gabel, Simester, and Timoshenko 2024).

For this study, we collaborate with a digital signage provider that operates digital screens and creates value for both retailers and manufacturing brands, according to the business model presented in Figure 2.¹ For retailers, it offers a new, high-margin, constant revenue stream after their initial investment in the

¹ This section and Figure 2 are based on personal communication with the management team of the digital signage provider, confidential reports provided to the brand manufacturers, and insights obtained from the retailer.

necessary in-store technology. For manufacturing brands, it represents a unique in-store advertising instrument and transparent reporting system that can calculate the returns on their ad spending. Thus, even if digital signage operates in retail stores, the actors most interested in its effectiveness are manufacturing brands that pay to promote their brands to shoppers at the POS. As part of its digital signage package, the provider we collaborate with offers reports of the effects of digital signage on the featured products, other products sold by the same brand, and competitive products. To obtain these reports, the manufacturing brands must provide global trade item numbers (GTINs) for the different product groups that can be recognized from shopping receipts. All the brands provided GTINs for featured products, but only 14% listed GTINs for their other products or competitive products. Thus, brand manufacturers seem primarily interested in the direct impact of digital signage on featured products, and their main request is information about any changes in purchase probability. That is, they want to know if more shoppers exposed to digital signage purchase the featured product.

Previous Research on Digital Signage

Extensive studies and empirical generalizations detail mobile and social media advertising effects (Bart, Stephen, and Sarvary 2014; Gordon et al. 2019), but only a handful have examined the effects of digital signage; an important shortcoming, considering 87% of all U.S. retail sales occur in brick-and-mortar stores (Goldberg 2022). In Table 1, we summarize existing studies of digital signage, which represent notable endeavors to contribute to this nascent field. Regarding the potential main effect, Roggeveen, Nordfält, and Grewal (2016) find the effect of digital signage depends on store size; Schweiger et al. (2023) instead indicate a positive effect. The inconsistent findings might stem from the greater vividness of digital screens (e.g., images projected on the floor in Schweiger et al. [2023]), implying that studies that feature lower vividness may underestimate digital signage. Other studies prioritize measures of overall sales in the retail store, which is too generic to inform the manufacturing brands that pay for the ads. Furthermore, rather than exposures to certain ads and their specific effects, most studies consider the combined, mutual effects of multiple advertising campaigns on overall outcomes. Finally, because advertising effects tend to be small, some studies are likely statistically underpowered. For example, Nanni and Ordanini (2024) indicate no differential effects of price- and nonprice-related content, but this result might stem from the sizes of their samples.

Conceptual Framework

Digital Signage and Purchase Probability of the Featured Products

In-store advertising, such as digital signage, can affect shoppers' decision-making at the POS (Chandon et al. 2009; Hwang and Thomadsen 2016; Zhang 2006). These effects can be explained by the two-step process of attention and appraisal

established by Inman, Winer, and Ferraro (2009). First, digital signage requires the shopper's attention to have any impact. Therefore, greater attention should exert a more salient effect on in-store decision-making. We propose that digital signage elicits attention because the screen locations are in highly frequented aisles (i.e., visual areas that capture a lot of attention), the content on the digital displays gets activated as shoppers approach the screen, videos elicit focal attention with moving elements, and audio amplifies the effects of the visual features. Such attention can be captured by exposure measures, which indicate the high likelihood that shoppers see the advertisement. Second, after shoppers have been exposed to the in-store advertising, they appraise it, which can lead to an advertising response, potentially including impulse buying. Therefore, we expect:

H₁: Exposure to digital signage increases the purchase probability of the featured products.

Apart from quantifying the effect of digital signage, we use our conceptual framework as a guiding tool to develop hypotheses on several moderators, as summarized in Figure 3. We consider five product-related features: the type of product (hedonic or utilitarian), brand popularity, whether a new product is featured, the product price, and whether there is a price cut. Because a unique feature of digital signage is its ability to adjust messages dynamically, we also account for four timing-related features. These include the day of the week, the time of the day, the weather, and the crowdedness in the store. Finally, we explore campaign-related factors that advertisers can control, the type of appeal and whether a promotional signal is used. Table 2 summarizes how these moderators link to the two theory-based mechanisms, self-control and variety seeking, that limit or increase the possibility of a response to digital signage. We use self-control and variety seeking to examine product, timing and campaign features. Both self-control, an individuals' ability to change their responses (Baumeister 2002), and variety seeking, an individuals' response to the psychological need for stimulation (McAlister and Pessemier 1982), have been used to understand unplanned purchases in prior work (Inman, Winer, and Ferraro 2009; Trivedi 1999). We suggest that when shoppers' self-control is lower and/or variety seeking is high, they are more likely to be influenced by digital signage exposure.

While self-control and variety-seeking tendency are psychological states that directly influence how shoppers respond to digital signage, dual processing, circadian rhythm, and experiential shopping are antecedents that shape these psychological states. Central versus peripheral processing reflects how much cognitive effort is involved, which is closely tied to self-control and variety seeking, the circadian rhythm influences energy levels and fatigue, which affect self-control and variety seeking, and experiential shopping reduces self-control and increase variety seeking. Notably, these antecedents are also interrelated. Shoppers may be more tired in the afternoon (due to their circadian rhythm), which can push them toward peripheral processing and make them more receptive to experiential shopping.

Table 1. Field Studies on Digital Signage at the Point of Sale.

Study	Experiments	Shoppers	Outcomes	Attention-Grabbing Features					Key Findings
				Exposure	Activation	Video	Sound	Contingencies	
Nordfält et al. (2014)	1	62,037	Store-level revenue	—	—	—	—	Type of appeal	Informational content increases and ambience content decreases sales.
Roggeveen, Nordfält, and Grewal (2016)	3	183,756	Store-level revenue	—	—	—	—	Store size, type of appeal	The effect of digital signage depends on store size. Only promotional content has a positive effect on sales.
Garaus, Wagner, and Bäck (2017)	1	200	Individual purchases	—	—	Yes	—	Type of appeal	Affective content increases impulse purchases and store loyalty.
Willems, Brengman, and Van de Sanden (2017)	1	100	Individual purchases	Yes	—	—	—	Placement: Entrance vs. register, type of appeal	No differences between the locations and between brand or price appeal.
Garaus and Wagner (2019)	1	88	Individual satisfaction	Yes	—	—	—	—	Digital signage at the register increases store satisfaction.
Schweiger et al. (2023)	2	20,632 190,000	Individual purchases, store-level revenue	—	—	Yes	Yes	Vividness, audio, smell	Inverted U-shaped relationship between vividness and sales. The addition of audio increases sales, whereas smell has no effect.
Nanni and Ordanini (2024)	2	7,009	Individual spending	—	—	—	—	Placement relative to product, type of appeal	No differences between price- and nonprice-related content for discounted products.
Our research	237	29,999,084	Individual purchases	Yes	Yes	Yes	Yes	Type of product, brand popularity, product novelty, price of product, price cut, day of week, time of day, weather, crowdedness, type of appeal, promotional signal	Exposure increases purchase probability on average by 8.1%. This effect is higher for hedonic, novel, and low-priced products, for popular brands, on weekends and later in the day, with better weather, for crowded stores, with emotional messages, and without promotional signals.

Notes: We only consider field studies with digital screens in this table. In our empirical setting, we cannot test all moderators from previous research. Namely, store size is constant in our study, all our stimuli are vivid with video and sound, and we do not use any olfactory stimuli.

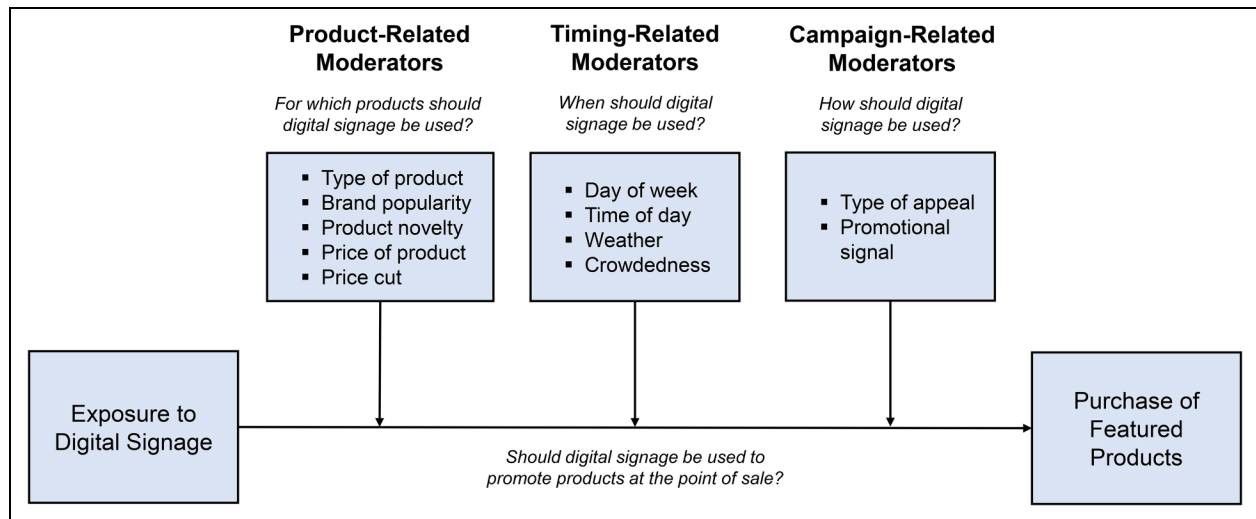


Figure 3. Conceptual Framework.

Table 2. Mechanisms and Antecedents Underlying the Moderating Effects.

	Theoretical Mechanisms		Antecedents			Net Effect
	Self-Control	Variety Seeking	Dual Processing	Circadian Rhythm	Experiential Shopping	
Product-Related Moderators						
H ₂ : Type of product	+	+	+		+	+
H ₃ : Brand popularity	+	—	+		—	+
H ₄ : Product novelty	+	+	—		+	+
H ₅ : Price of product	—	—	—		+/—	—
H ₆ : Price cut	+	+	+		+/—	+
Timing-Related Moderators						
H ₇ : Day of week	+/—	+		+	+	+
H ₈ : Time of day	+	+		+	+	+
H ₉ : Weather	+	+		+	+	+
H ₁₀ : Crowdedness	+	—	+		—	+
Campaign-Related Moderators						
H ₁₁ : Type of appeal	+	+	+		+	+
H ₁₂ : Promotional signal	+	+	+		—	+

Notes: Expected effects refer to type of product: hedonic, day of week: weekend, and type of appeal: emotional. The two theory-based mechanisms and three antecedents are overviewed in Web Appendix A. We cannot separate them empirically, but we use them to derive predictions about the moderation effects.

Product-Related Moderators

Type of product. Hedonic products provide emotional and sensory gratification, whereas utilitarian products serve functional needs (Dhar and Wertenbroch 2000). Exposure to advertising for hedonic products reduces activation in brain regions linked to self-control, and shoppers are likely to indulge in the temptation (Vohs and Heatherton 2000). Similarly, hedonic products show significantly more variety-seeking behavior than utilitarian products (Trijp, Hoyer, and Inman 1996). Moreover, dual processing such as the elaboration likelihood model (Petty, Cacioppo, and Schumann 1983) can be inferred to suggest that hedonic products are more likely processed through the peripheral route while

utilitarian cues are centrally processed, which might make hedonic products more influenced by environmental cues such as digital signage (Dijksterhuis et al. 2008). A similar conclusion can be drawn from research that shows that experiential shoppers are more likely to preplan utilitarian purchases, whereas hedonic purchases are more impulse-driven (Ramanathan and Menon 2006). Thus, digital signage should be more effective for hedonic products that evoke lower self-control and more variety seeking:

H₂: Digital signage is more effective for hedonic products than for utilitarian products.

Brand popularity. Brand popularity refers to the level of recognition, admiration, and preference that a brand enjoys among shoppers (Keller 2013). Shoppers that encounter more popular brands perceive lower risk, which lowers self-control and makes purchasing more impulsive (Sheth and Venkatesan 1968). However, variety-seeking behavior can lead shoppers to intentionally move away from popular brands in pursuit of novelty (Ratner and Kahn 2002). Although both mechanisms may be relevant, we expect self-control to dominate in our context because more popular brands require less processing (Campbell and Keller 2003) and therefore fit better with peripheral route processing at the POS. Thus:

H₃: Digital signage is more effective for more popular brands.

Product novelty. In our study, product novelty is defined as new products recently introduced to the assortment of the retailer. Shoppers exposed to digital signage featuring novel products might anticipate the joy of acquiring something new, leading to less self-control (Rook and Fisher 1995). Novel products further evoke variety seeking, a key experiential shopping motive (Min and Schwarz 2022). The activation of novelty seeking triggers curiosity and increases impulse buying. From a dual-process perspective, however, featuring a novel product on digital signage could evoke processing through the central route, given that it is unknown to the shopper (Campbell and Keller 2003). Nevertheless, overall we expect:

H₄: Digital signage is more effective for novel products.

Product price. Shoppers have less self-control and are more tempted to purchase impulsively when the price of the product is low (Cobb and Hoyer 1986). Even when they leave room for impulse items, their spending remains close to their original mental budget, because they work to prevent overspending (Stilley, Inman, and Wakefield 2010). Moreover, a higher price tends to suppress variety seeking (McAlister and Pessemier 1982), while a lower product price minimizes the need for further cognitive elaboration, increases peripheral processing, and thus facilitates impulsive buying (Dijksterhuis et al. 2008). Experiential shoppers are often less price-focused because their motivation stems from hedonic value rather than strict economic rationality (Hirschman and Holbrook 1982). Still, overall we expect:

H₅: Digital signage is more effective for lower-priced products.

Price cut. Marketers often use discounts (i.e., price promotions) to trigger impulse purchases (Iyer et al. 2020), although previous research differentiates between promotional signals as proxies for price cuts and actual discounts (Inman, McAlister, and Hoyer 1990). We focus on actual discounts and discuss promotional signals among the campaign-related

moderators.² A price cut lowers shoppers' self-control and increases variety seeking because the reduced price minimizes the perceived risk (Kahn and Raju 1991) and offers a strong cue that requires less processing (Dijksterhuis et al. 2008). Experiential shoppers, while willing to pay more, still enjoy the psychological gratification of "getting a good deal" (Darke and Dahl 2003). Thus:

H₆: Digital signage is more effective for products with a price cut.

Timing-Related Moderators

Day of week. Most consumers are busier during the weekdays and take more time to relax and wind down from work-related stress during the weekend as a break in their routine. When shoppers are in a busy mindset, a sense of self-importance arises and self-control increases (Kim, Wadhwa, and Chattopadhyay 2019). Self-control lens also offers an opposing rationale, suggesting that when shoppers are pressed for time during the week, less elaborate decision-making is done and self-control is lower. This perspective is in line with Fox and Hoch's (2005) finding that shoppers do more cherry-picking on the weekend when they have more time. Research has demonstrated that consumers are more depleted toward the end of the week (Fritz et al. 2010), and tired consumers seek more variety (Huang et al. 2019). This should make shoppers more receptive to digital signage at the POS on weekends. Thus:

H₇: Digital signage is more effective during weekends than weekdays.

Time of day. As the day progresses and many decisions have been made, consumers' level of self-control decreases, leading to more impulsive behavior (Vohs et al. 2008). This is in line with research using the circadian rhythm that shows that consumers stick more closely to their shopping lists and do less variety seeking in the morning (Gullo et al. 2019). These two approaches align with the shopping orientation: When consumers shop early in the morning, they are rather task-oriented, while later in the day they follow a more experiential approach, allowing for more stimulation and variety seeking (Kaltcheva and Weitz 2006). Thus:

H₈: Digital signage is more effective later in the day.

Weather. Weather conditions affect consumers' daily behaviors; for example, Roehm and Roehm (2005) found that good weather with more sunshine lowers shoppers' self-control and increases their variety seeking. The circadian rhythm provides an explanation for the influence of weather on shopping

² Actual price discounts are not featured in the content of the digital signage because the same ads typically run for several weeks on the screen, whereas the retailer's actual discounts usually change on a weekly basis.

behavior (Gullo et al. 2019). When shoppers' arousal is elevated by sunlight, they explore a greater variety of products. Research further demonstrated that experiential shopping is more prevalent when the weather is good (Murray et al. 2010). Thus:

H₉: Digital signage is more effective with better weather conditions.

Crowdedness. In line with Aydinli et al. (2021), crowdedness refers to the experience of social density, defined as the number of people per unit area. Crowded environments are distracting, which reduces shoppers' perceived control (Blut and Iyer 2020). Moreover, in crowded environments, consumers rely on quick intuitive judgements that are in line with peripheral processing rather than central processing (Hock and Bagchi 2018). However, crowded stores may discourage exploration, reducing variety seeking when crowdedness causes stress and leads to simplified decision-making (Machleit, Eroglu, and Mantel 2000). Nevertheless, given that that crowded environments may also heighten the public visibility of consumption choices and increase consumers' variety seeking (Ratner and Kahn 2002), we expect:

H₁₀: Digital signage is more effective when crowdedness is high.

Campaign-Related Moderators

Type of appeal. Messages with emotional appeal rely on drama, mood, and other emotion-eliciting strategies to target the shopper's emotions, whereas messages with informational appeal feature facts, statistics, and logical arguments to convince consumers (Chandy et al. 2001). Taking the self-control lens, emotional appeal is found to be an important driver of impulsive buying, as it disrupts consumers' self-control (Pham 2007). An informational message requires thoughtful central processing, while emotional messages are better suited to peripheral processing (Petty, Cacioppo, and Schumann 1983). An emotional appeal is also better suited to address experiential shoppers (Babin, Darden, and Griffin 1994). Finally, the positive affect from emotional appeal can increase variety seeking (Menon and Kahn 1995). Thus:

H₁₁: Digital signage is more effective with emotional than informational appeal.

Promotional signal. In addition to price cuts, the mere presence of a promotional signal can influence purchasing behavior as promotional signals lower self-control (Inman, McAlister, and Hoyer 1990). Promotional signals can provide a final push to purchase a product and make it easier for consumers to justify giving up self-control to attain immediate gratification, which prompts more impulse purchases (Iyer et al. 2020). Promotional signals can trigger variety seeking (Trivedi 1999), minimize the need for cognitive elaboration and increase peripheral processing (Dijksterhuis et al. 2008), and provide psychological gratification (Darke and Dahl 2003). Thus:

H₁₂: Promotional signals increase the effectiveness of digital signage.

Field-Experimental Methodology

Data Collection

Digital signage installed in ten stores, each with five screens (50 total), provides the data for our field-experimental approach. These stores are in the same region of a western European country and managed by the same retailer. All the stores carry mainly food and household items, feature a sales space of around 108,000 square feet (i.e., smaller than a typical Walmart Supercenter with 182,000 square feet), and earn average annual sales of \$25 million. These stores aim to deliver one-stop shopping, and consumers typically arrive with extensive shopping lists in mind, such that they set aside relatively substantial time for the shopping trip. The screens are attached to the ceiling in the middle of main aisles that attract shopper traffic (see Figure 1). After an initial familiarization period, we conducted 237 field experiments on 1,321 different days between 2018 and 2022 (stores are closed on Sundays).³

Summary statistics for the 237 campaigns are in Web Appendix B. During the study period, the digital signage system did not engage in targeting for specific ad campaigns nor was any other targeting or optimization in place. The manufacturing brands pay for a previously agreed amount of daily shopper exposure, such that the campaigns differ from regular in-store advertising that focuses on store traffic rather than exposure.

As the depiction of the digital signage system in Figure 4, Panel A, indicates, each campaign's procedure was similar. If not approached by a shopper with a shopping cart, the screens constantly play generic and static retailer content without any sound or references to specific products (e.g., general marketing messages, event information). An advertisement only starts to play if a shopper with a shopping cart is within 5–10 meters of the screen, in the same aisle as the screen, and facing the screen. Then the system gets activated by an invisible RFID tag in the shopping cart, such that it begins playing one of the ads currently installed in the system, according to a random selection. In addition to the video, a directional loudspeaker targets the shoppers. The RFID reader connected to each screen identifies which shoppers with shopping carts were exposed to which ads. At the end of the shopping trip, the RFID tag in the shopping cart links with the cash register to match the exposure with the shopper's receipt, detailing the products purchased (but not any personal information about the shopper).⁴ We obtained full access to the scanner data for all stores and the whole study period; for each shopper, we know the exact day and time of the visit, whether they were exposed to any ads, and all items they bought.

³ The provider ran these campaigns for its manufacturing brand clients, which developed the ads and chose the campaign duration. We did not influence any aspects of the campaigns or field-testing methodologies used.

⁴ The cooperating retailer fully respects the privacy of customers, in line with the General Data Protection Regulation (GDPR).

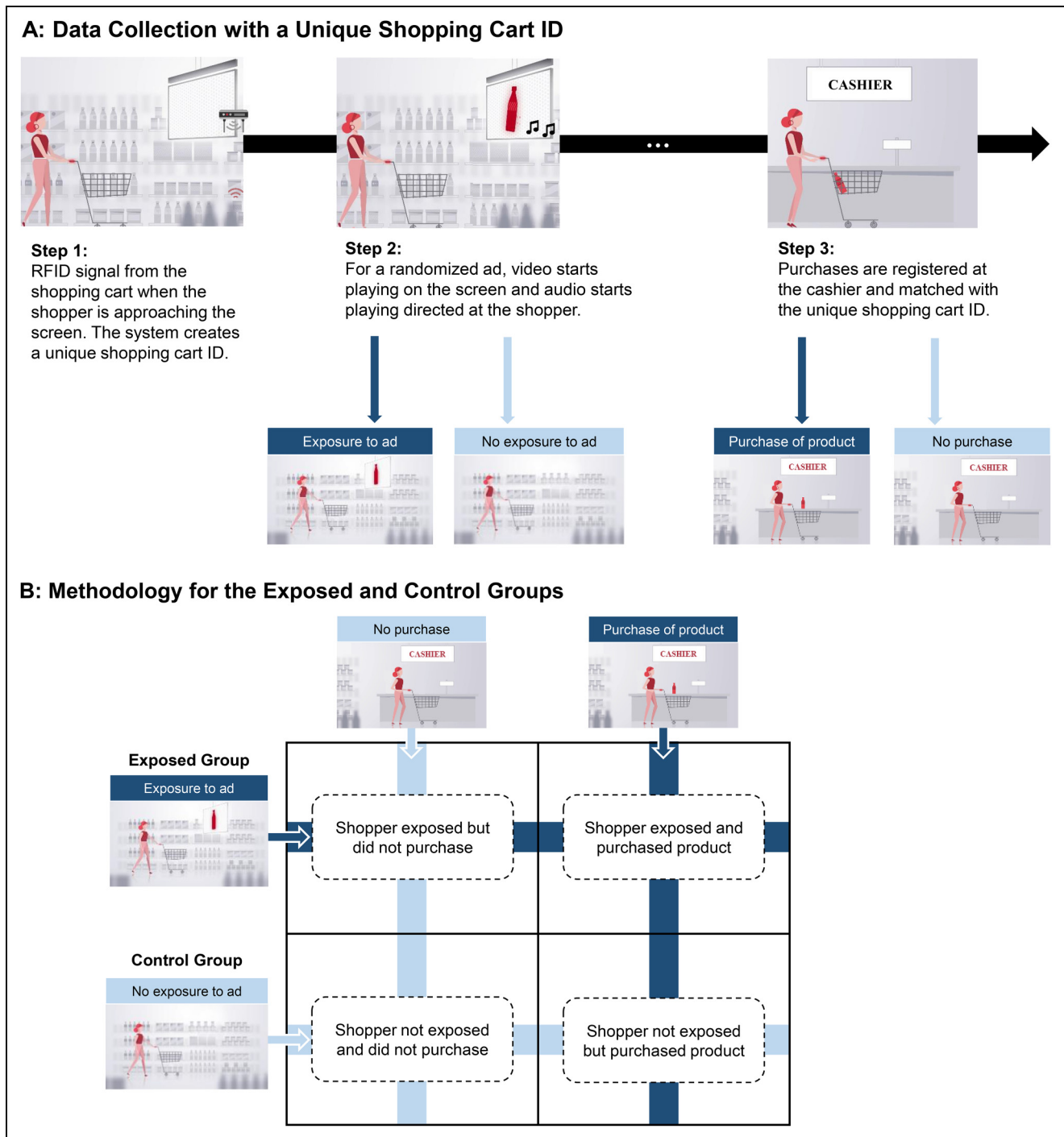


Figure 4. Data Collection and Methodology.

Methodology

Our analytical approach follows the same logic as digital advertising testing in prior online field experiments (Bart, Stephen, and Sarvary 2014). Figure 4, Panel B, provides an overview

of the experimental conditions. If shoppers approach and experience random exposure to an ad, they enter the exposed group for this specific campaign; if they were not exposed or instead saw a different ad, they enter the control group. The outcome of interest is purchase probability (i.e., whether

the shopper bought a related product [yes or no]), for which information was automatically extracted from the receipts.⁵ This methodology enables us to isolate the effect of digital signage from other potential determinants, such as shopper traits or resources, through randomization. We also can exclude the effects of other marketing stimuli, outside and inside the store, by keeping them constant (i.e., both groups visit the same store on the same day, so all other advertising effects are constant across groups) or else controlling for their potential effects (e.g., price cuts).

Critically, we measure the intention-to-treat and not the treatment itself, because shoppers in the exposed group might not have paid close attention to the screen.⁶ This approach might lead us to underestimate the effect of digital signage, but it offers the clear advantage of reflecting the “true effect” of digital signage administered in the field and thereby affirms the ecological value of our studies (Van Heerde et al. 2021). Moreover, using an intention-to-treat analysis can reduce the risk of bias due to the systematic imbalance of baseline characteristics that arises in as-treated analyses (Gupta 2011). An as-treated analysis of digital signage specifically would be biased because shoppers who pay attention to in-store advertising are more likely to exhibit greater impulse buying tendencies (Iyer et al. 2020). Noncompliant shoppers would be excluded from such an as-treated analysis, and the digital signage effect then would be biased upward.

Estimation and Results

Allocation of Shoppers and Model-Free Evidence

Only shoppers with a cart can join the exposed group; shoppers without a cart always get assigned to the control group (because no RFID ever prompts the ads for these shoppers). Acknowledging this systematic bias and the differences in total spending and number of items between such groups (both $p < .001$), we limit our sample to the 10,504,430 shoppers who used shopping carts and frequented the stores during the study period (i.e., purchased at least one item and received a receipt). Each shopper with a shopping cart participated in an average of 2.86 field experiments (see Web Appendix C): 39% of these shoppers only joined exposed groups, 36% only entered control groups, and 25% were assigned to both exposed and control groups during the course of their shopping trip. The layout of the stores makes it unlikely that any shopper with a cart could avoid all in-store screens. Thus, the shoppers who were not exposed to any of the ads probably visited at a time when the retailer’s algorithm did not play ads or else

followed other shoppers, such that they were bystanders to those other shoppers’ ad exposure.⁷

We display the model-free effect of exposure in Web Appendix D: Exposure leads to an average purchase probability increase of 50%, and 87% of campaigns had a positive effect. However, this effect may be at least partly driven by the fact that shoppers who spend more time in the shop are more likely to be exposed and more likely to purchase. We carefully address this self-selection effect in our data, as detailed in the following section.

Moderators and Controls

In addition to the experimental data (random exposure to ads) and the scanner data (receipts of purchases of related products), we include data reflecting perceptual and objective measures of the advertised products and ad content, as established by three native-speaking, independent coders who were not familiar with the research question. With access to all 237 ad campaigns and a coding scheme, the coders identified the type of product and type of appeal, as we detail in Web Appendix E. They could watch the campaigns multiple times, and they resolved any discrepancies in coding through discussion.

The other moderators were derived from the scanner data, external data sources, or manual coding of objective features. Novel products were those that were recently introduced to the stores, the price of the products was the actual price on the receipt in euros, and price cuts indicate whether the products were on discount at the time of purchase. We extracted the day of the week and time of day from the time stamp of the receipt. To capture the weather, we used the OpenWeather API to obtain sunshine, and we also controlled for temperature and rain. Crowdedness of the store was measured by the total number of receipts in the hour of the store visit. The coders also gauged brand popularity and the presence of promotional signals.

We include some additional control variables that may affect both attention and purchases. In addition to accounting for potential selection and learning effects, we include the number of items and total spending by each shopper. By noting exposure to different ads, we consider the potential that the focal ad effect could grow weaker. Furthermore, we control for campaign wearout, the daily count from the first day since the advertising campaign started, the creativity of the ad, and any human presence in the ad. We summarize all measures in Web Appendix F, and correlations and descriptives are in Web Appendix G.

Addressing Endogeneity Caused by Selection Effects

Two types of potential selection effects may be present in our data: Shoppers might self-select to spend more or less time in the store, and manufacturing brands might self-select into using digital signage with specific content. We address both effects.

⁵ The GTINs for all products featured in the ad were provided by manufacturing brands, reflecting a standard barcode and numbering system used in global trade to identify a specific product type, in a specific packaging configuration, from a specific manufacturer.

⁶ Due to the limitations of our GDPR-compliant data, we cannot capture shoppers’ attention, because such a measurement would require us to visually track all shoppers. However, a recent survey indicates that 71% of shoppers notice digital displays in the store (Vibonomics 2024).

⁷ Bystanders do not trigger the ad but are exposed to (some part of) it. Any influence of this unnoticed exposure would be included in the control group and therefore make our estimates more conservative.

Shoppers' self-selection. Shoppers self-select to spend more or less time in the store, and those who spend more time are more likely to pass several screens, trigger ads, and enter one or more exposed groups. Such shoppers also are more likely to be influenced by digital signage, because they seemingly have greater time availability, which increases impulse buying (Iyer et al. 2020). This could distort the randomization, so we use a Heckman selection model and include an instrument to correct for this self-selection.⁸

In the first stage, we use a probit model to predict shoppers' exposure based on the total number of items purchased and their total spending, which function as proxies for shopping duration. Shoppers who purchase more items and spend more likely have been in the store longer and passed more shelves, which increases the likelihood that they trigger the system. We also include an exogenous instrument that influences exposure but is unrelated to the shopper's purchase decision, namely, advertising pressure. Depending on the ad spending of the manufacturing brands, the system calculates daily exposure goals, equal to the overall number of exposures a certain ad should receive each day (i.e., advertising pressure). This target is unknown to shoppers but increases exposure, such that it might influence their purchase behavior but only through increased exposure. Thus, this instrument is both relevant and exogenous. We further control for potential day-of-week, time-of-day, and crowdedness effects on exposure. Specifically, the first-stage probit model is:

$$EXP_i^* = z_i^{EXP} \lambda^{EXP} + \eta_i^{EXP}, \quad (1)$$

where EXP_i^* denotes a latent measure with an observed binary response indicator $EXP_i = I\{EXP_i^* > 0\}$, z_i^{EXP} captures the variables that influence exposure, λ^{EXP} is the unknown parameter vector, and η_i^{EXP} is a random error. We include shoppers' total number of items, total spending (instrumented), day of the week, hour of the store, and crowdedness in z_i^{EXP} . The first-stage regression empirically confirms that advertising pressure is a strong predictor of increased ad exposure ($\beta = 4.8$, $p < .001$; χ^2 test = 2,587,571, $p < .001$; see Web Appendix H).

In the second stage, we use the estimates of λ^{DPE} and $z_i^{DPE} \lambda^{DPE}$ to compute an inverse Mills ratio (IMR) as a bias correction term for each shopper when predicting purchase probability:⁹

$$IMR_EXP_i = \begin{cases} \frac{\phi(z_i^{EXP} \lambda^{EXP})}{\Phi(z_i^{EXP} \lambda^{EXP})} & \text{if } EXP = 1, \\ -\frac{\phi(z_i^{EXP} \lambda^{EXP})}{1 - \Phi(z_i^{EXP} \lambda^{EXP})} & \text{if } EXP = 0, \end{cases} \quad (2)$$

where Φ is the probability density and ϕ is the cumulative distribution of the standard normal distribution. We include the

exposure correction term when estimating the effects of exposure and the moderators on the purchase probability of the focal product with Equation 4.

Brand manufacturers' self-selection. Only brand manufacturers that expect to benefit use digital signage (as is true of any advertising decision). However, such self-selection is unlikely to bias the estimates, because brand manufacturers rarely decide explicitly whether to use digital signage. Due to the newness of the digital signage system, the digital signage provider worked with a leading national media agency, which offered exposure on digital signage as part of a broader media package to its customers. Thus, the influence of brand manufacturers' strategic decision to use digital signage is minimal. In addition, the brand manufacturers had no previous direct or indirect experience with digital signage and whether it might be effective for them. The digital signage system we study is the first to capture purchase behavior and effectiveness, and our data collection started with the first campaign run by the system. Thus, different brand manufacturers used the digital signage option for different promotions featuring well-known and unknown brands, existing and novel products, and emotional and informational appeals. The effectiveness of certain campaigns was not publicly shared either. The current study represents the first systematic attempt to understand the effects of product, timing and campaign-related characteristics. Finally, we empirically control for a potential learning effect over time (i.e., days since the start of the system) that should capture any informal communication among brand manufacturers.

If brand manufacturers decide to use digital signage, they might try to maximize its effectiveness. They cannot alter the context, but they have control over the content of the ad campaigns (i.e., type of appeal, promotional signal, creativity, and presence of humans), and this strategic choice is unobservable to us. To correct for potentially endogenous content, we use the control function approach as detailed in Web Appendix I. We use the average content of other campaigns in the same product categories as instruments:

$$TOP_j = \beta_0 + \beta_{1-4} \sum_{n=1}^4 INS_{nj} + \beta_{5-11} \sum_{m=1}^7 CON_{mj} + \varepsilon, \quad (3a)$$

$$PRS_j = \beta_0 + \beta_{1-4} \sum_{n=1}^4 INS_{nj} + \beta_{5-11} \sum_{m=1}^7 CON_{mj} + \varepsilon, \quad (3b)$$

$$CRE_j = \beta_0 + \beta_{1-4} \sum_{n=1}^4 INS_{nj} + \beta_{5-11} \sum_{m=1}^7 CON_{mj} + \varepsilon, \quad (3c)$$

$$POH_j = \beta_0 + \beta_{1-4} \sum_{n=1}^4 INS_{nj} + \beta_{5-11} \sum_{m=1}^7 CON_{mj} + \varepsilon, \quad (3d)$$

where TOP_j , PRS_j , CRE_j , and POH_j are the potentially endogenous content variables type of appeal, promotional signal,

⁸ Another potential option would be propensity score matching. However, the system is GDPR compliant, so we are bound by law and have no exogenous information about shoppers that might not be influenced by ad exposure.

⁹ The ad exposure to a specific campaign is randomized. The same shopper may be in the exposed group for one campaign and in the control group for another campaign. This randomization reduces the potential impact of unobserved factors and enhances the credibility of the causal effect of digital signage.

creativity, and presence of humans, INS_{nj} represents the four instruments, CON_{nj} is a vector of seven campaign-level controls, and ϵ is the error term. The results are unaffected by the inclusion of the control functions, which suggests unbiased estimates, so we ultimately use the more efficient models (Herhausen et al. 2025).

Model Specification

All variance inflation factors are below 3.70 (mean = 1.87). By using robust and clustered standard errors in all analyses, we account for the nested data structure (i.e., the same shopper can appear multiple times in the dataset). We median-centered price to acknowledge its high skewness and mean-centered all other predictors for the interaction terms:

$$\begin{aligned} \text{logit}(\text{PUR}_i) = & \beta_0 + \beta_1 \text{EXP}_i + \beta_{2-12} \sum_{n=1}^{11} \text{MOD}_{ni} \times \text{EXP}_i \\ & + \beta_{13-23} \sum_{n=1}^{11} \text{MOD}_{ni} + \beta_{24-29} \sum_{m=1}^6 \text{CON}_{mi} \\ & \times \text{EXP}_i + \beta_{25-33} \sum_{o=1}^9 \text{CON}_{oi} + \beta_{34} \text{IMR_EXP}_i \\ & + \beta_{35-43} \sum_{p=1}^9 \text{STO}_{pi} + \beta_{44-54} \sum_{q=1}^{11} \text{MON}_{qi} + \epsilon, \end{aligned} \quad (4)$$

where PUR_i is the purchase of the focal products by shopper i (1 = purchased, 0 = not purchased), EXP_i is shopper i 's exposure to the focal campaign (1 = exposed, 0 = not exposed), the vector $\text{MOD}_{ni} \times \text{EXP}_i$ represents the hypothesized moderating effects, the vector MOD_{ni} represents the main effects of the moderators, the vector $\text{CON}_{mi} \times \text{EXP}_i$ represents additional interaction effects with controls, the vector CON_{oi} represents the control variables, IMR_EXP_i is the exposure correction term, the vector STO_{pi} contains store fixed effects, the vector MON_{qi} represents the month fixed effects, and ϵ is the error term.

Hypothesis Tests

Main effect of exposure. Model 1 in Table 3 reveals a positive effect of being exposed to the ad on purchase probability ($\beta = .078$, $p < .001$, $OR = 1.081$). Thus, being exposed to digital signage increases purchase probability by 8.1%,¹⁰ in support of H_1 .

We ran several robustness tests for this effect, as detailed in Web Appendix J. Whether we estimate the models without selection correction ($\beta = .093$, $p < .001$, $OR = 1.097$), include total spending

instead of residuals ($\beta = .076$, $p < .001$, $OR = 1.079$), include number of unique stockkeeping units ($\beta = .064$, $p < .001$, $OR = 1.066$), number of product categories ($\beta = .061$, $p < .001$, $OR = 1.063$), or number of sectors ($\beta = .059$, $p < .001$, $OR = 1.061$) instead of number of items, or consider only the subset of shoppers that appear in both the exposed and control groups to control for unobserved differences between groups ($\beta = .090$, $p < .001$, $OR = 1.094$), the effects remain robust. The exposure effect is also robust when using weekly ($\beta = .077$, $p < .001$, $OR = 1.080$) or product category ($\beta = .124$, $p < .001$, $OR = 1.130$) fixed effects.

Moderating effects. The product type $\times$ exposed effect ($\beta = .131$, $p < .001$, $OR = 1.139$) indicates that the effect of being exposed is stronger for hedonic than for utilitarian products, as we proposed in H_2 . The brand popularity $\times$ exposed effect ($\beta = .024$, $p < .001$, $OR = 1.025$) and the product novelty $\times$ exposed effect ($\beta = .188$, $p < .001$, $OR = 1.206$) are positive, in support of H_3 and H_4 . The price $\times$ exposed effect is negative ($\beta = -.050$, $p < .001$, $OR = .951$), in line with H_5 . The price cut $\times$ exposed effect is not supported ($\beta = -.006$, $p = .509$, $OR = .994$), in contrast with H_6 . In line with our prediction in H_7 , the weekend $\times$ exposed effect ($\beta = .042$, $p < .001$, $OR = 1.043$) indicates that digital signage is more effective on the weekend. The time of day $\times$ exposed effect ($\beta = .025$, $p < .001$, $OR = 1.025$) indicates that the exposed effect is stronger later in the day, in support of H_8 . We find a positive weather $\times$ exposed effect ($\beta = .058$, $p < .001$, $OR = 1.060$), in support of H_9 . The crowdedness $\times$ exposed effect is positive ($\beta = .011$, $p < .001$, $OR = 1.011$), as we predicted in H_{10} . The appeal type $\times$ exposed effect is positive ($\beta = .012$, $p < .001$, $OR = 1.012$), in support of H_{11} . The promotion signal $\times$ exposed effect ($\beta = -.101$, $p < .001$, $OR = .904$) does not support H_{12} . Table 4 summarizes the findings; Figure 5 displays the predicted margins for the moderating effects graphically.

Additional Interaction Effects

We further find a negative wearout campaign $\times$ exposed effect ($\beta = -.025$, $p < .001$, $OR = .975$) and a positive learning $\times$ exposed effect ($\beta = .034$, $p < .001$, $OR = 1.034$). That is, the same campaign becomes less effective over time, but digital signage generally becomes more effective. We also find negative rain $\times$ exposed ($\beta = -.056$, $p < .001$, $OR = .945$) and human presence $\times$ exposed ($\beta = -.112$, $p < .001$, $OR = .894$) effects, providing additional support for the weather effect and suggesting that human presence in the ad takes focus away from the product, thereby diminishing persuasion.

We report further analyses in Web Appendix K, including day-of-week dummies, time-of-day dummies, and potential three-way interactions. Results using day-of-week dummies generally confirm our main analyses. The exposure effect is stronger on Saturdays with 11%, and most weekdays do not differ, except Tuesdays with an exposure effect of 13%. This finding might reflect synergies with the retailer's weekly leaflet, which is updated each Tuesday.

¹⁰ To ease interpretation, we report relative changes in percent, which refer to multiplicative changes in odds between exposed and not exposed shoppers. For small probabilities like the ones we study odds and probabilities are almost identical (we consider purchase probabilities for specific products among all shoppers in a supermarket).

Table 3. Results for the Main Analysis.

	Model 1					Model 2				
	β	SE	z	OR	p	β	SE	z	OR	p
Hypotheses										
H ₁ : Exposed to digital signage	.078	.004	18.87	1.081	.000	.050	.009	5.36	1.051	.000
H ₂ : Type of product $\times$ exposed						.131	.011	11.72	1.139	.000
H ₃ : Brand popularity $\times$ exposed						.024	.005	4.82	1.025	.000
H ₄ : Product novelty $\times$ exposed						.188	.012	15.33	1.206	.000
H ₅ : Price of product $\times$ exposed						-.050	.007	-7.25	.951	.000
H ₆ : Price cut $\times$ exposed						-.006	.010	-.66	.994	.509
H ₇ : Day of week $\times$ exposed						.042	.010	4.39	1.043	.000
H ₈ : Time of day $\times$ exposed						.025	.001	21.99	1.025	.000
H ₉ : Weather $\times$ exposed						.058	.012	5.00	1.060	.000
H ₁₀ : Crowdedness $\times$ exposed						.011	.001	7.16	1.011	.000
H ₁₁ : Type of appeal $\times$ exposed						.012	.003	3.54	1.012	.000
H ₁₂ : Promotional signal $\times$ exposed						-.101	.023	-4.49	.904	.000
Additional Interactions										
Wearout campaign $\times$ exposed						-.025	.002	-14.60	.975	.000
Learning effect $\times$ exposed						.034	.002	19.45	1.034	.000
Temperature $\times$ exposed						.014	.008	1.71	1.015	.088
Rain $\times$ exposed						-.056	.016	-3.56	.945	.000
Creativity $\times$ exposed						.002	.004	.58	1.002	.565
Human presence $\times$ exposed						-.112	.011	-10.32	.894	.000
Controls										
Wearout campaign	-.081	.001	-84.34	.923	.000	-.067	.001	-50.19	.935	.000
Learning effect	.113	.001	111.05	1.120	.000	.099	.001	77.41	1.104	.000
Temperature	.106	.007	14.68	1.111	.000	.096	.008	11.66	1.101	.000
Rain	.038	.010	3.93	1.038	.000	.075	.013	5.60	1.078	.000
Creativity	-.392	.003	-152.85	.676	.000	-.399	.004	-113.63	.671	.000
Human presence	-.125	.007	-17.31	.882	.000	-.074	.010	-7.81	.928	.000
Exposed to different ads	-.065	.002	-29.36	.937	.000	-.065	.002	-29.06	.937	.000
Number of items	2.108	.008	263.55	8.231	.000	2.101	.008	260.34	8.172	.000
Total spending	.189	.007	28.30	1.209	.000	.187	.007	27.44	1.205	.000
Type of product	-.012	.007	-1.76	.988	.079	-.069	.010	-7.03	.934	.000
Brand popularity	.290	.003	97.76	1.336	.000	.276	.004	66.26	1.318	.000
New product	1.734	.008	222.08	5.664	.000	1.646	.011	154.13	5.187	.000
Price of product	-.436	.004	-112.87	.647	.000	-.418	.005	-84.32	.658	.000
Price cut	.379	.006	64.56	1.460	.000	.382	.008	48.33	1.465	.000
Day of week	.115	.006	19.67	1.122	.000	.094	.008	12.14	1.098	.000
Time of day	.008	.001	12.42	1.008	.000	-.005	.001	-5.50	.995	.000
Weather	.072	.007	9.61	1.074	.000	.038	.010	3.99	1.039	.000
Crowdedness	-.016	.001	-11.99	.984	.000	-.020	.001	-13.59	.980	.000
Type of appeal	.421	.002	174.55	1.524	.000	.409	.003	135.24	1.505	.000
Promotional signal	.557	.014	38.66	1.746	.000	.591	.019	30.36	1.806	.000
Selection correction	-.180	.011	-16.53	.836	.000	-.207	.011	-18.26	.813	.000
Fixed Effects										
Store			Included					Included		
Month			Included					Included		
Log-likelihood			-1,455,492.20					-1,454,428.70		
N			29,999,084					29,999,084		

Notes: β = unstandardized coefficients, SE = robust standard errors, OR = odds ratios. Probit models are in Web Appendix L.

A robustness test with time-of-day dummies generally confirms a linear positive effect with one notable exception: The exposure effect is very high at 8 a.m., reaching 31%, then

drops to a minimum around lunchtime, before it increases again in the afternoon and evening. Perhaps shoppers need stimulation first thing in the morning, leading them to

Table 4. Overview of Results and Findings.

Hypothesis	Previous Research	Result	Summary of Findings
Should digital signage be used to promote products at the point of sale?			
H ₁ : Effect of digital signage	Mixed effects	✓	Exposure to digital signage increases shoppers' purchase probability of the featured products on average by 8.1%.
For which products should digital signage be used?			
H ₂ : Type of product	Mixed effects	✓	Higher effect for hedonic (vs. utilitarian) products.
H ₃ : Brand popularity	None	✓	Higher effect for more popular brands.
H ₄ : Product novelty	Positive effect	✓	Higher effect for novel (vs. existing) products.
H ₅ : Price of product	None	✓	Higher effect for lower-priced products.
H ₆ : Price cut	None	✗	Effect does not change for products with price cut.
When should digital signage be used?			
H ₇ : Day of week	None	✓	Higher effect for weekends (vs. weekdays).
H ₈ : Time of day	None	✓	The effect increases over the day.
H ₉ : Weather	None	✓	Digital signage is more effective with more sunshine.
H ₁₀ : Crowdedness	None	✓	Crowdedness increases the effect of digital signage.
How should digital signage be used?			
H ₁₁ : Type of appeal	Mixed effects	✓	Higher effect for emotional (vs. informational) messages.
H ₁₂ : Promotional signal	Mixed effects	✗	Promotional signals decrease the effect.
Additional Research Question		Summary of Findings	
Does the placement of digital signage relative to the featured products influence its effectiveness?		We find a negative interaction effect between distance to the screen and exposure: Higher effect for products that are closer to the screen.	
Do exposed shoppers spend more (or less) on the featured products than shoppers not exposed when they purchase?		Exposure to digital signage does not affect spending for the featured products for those shoppers that purchase.	
How does exposure influence switching between the featured products and other products of the same brands and switching between the featured products and competitive products from other brands?		Exposure to digital signage creates original demand for the focal products. Shoppers exposed to an ad for specific products have a higher purchase probability for other products from the same brand, a lower purchase probability for competitive products, and a higher purchase probability for the overall category.	
Does exposure lead to purchase acceleration (i.e., stockpiling of the featured products)?		Digital signage does not lead to purchase acceleration and stockpiling of shoppers, in contrast to price discounts.	

Notes: We only consider previous research on the effects of digital signage at the point of sale in this table.

engage in more variety-seeking behavior. If consumers need stimulation in the early morning, they may be more (less) receptive to ads for hedonic (utilitarian) products. We find a negative three-way interaction for exposed $\times$ time of day $\times$ product type ($\beta = -.007$, $p = .001$, OR = .993), such that the increase during the day is indeed higher for utilitarian products.

Consumers tend to be busier during weekdays, so they may be more receptive to hedonic products. However, we find no three-way interaction for exposed $\times$ weekend $\times$ product type ($\beta = -.017$, $p = .338$). That is, the product type effects do not differ between weekdays and weekends.

A fit between the type of product and type of appeal, such that hedonic (utilitarian) products are combined with emotional (informational) appeals, could increase the effectiveness of digital signage. However, we find a negative three-way interaction for exposed $\times$ product type $\times$ appeal

type ($\beta = -.033$, $p < .001$, OR = .967), such that both utilitarian and hedonic products perform best with emotional appeals.

We do find three-way interaction effects between exposure, the type of product, and sunshine ($\beta = .071$, $p < .001$, OR = 1.073) and between exposure, the type of product, and temperature ($\beta = -.150$, $p < .001$, OR = .861) but not for exposure, the type of product, and rain ($\beta = -.016$, $p = .665$). These findings indicate that in our sample, sunshine increases the exposure effect for hedonic products more than utilitarian products, while the exposure effect does not differ between hedonic and utilitarian products for high temperatures.

Additional Analyses

The field experiments show that shoppers exposed to digital signage exhibit a higher purchase probability for the featured

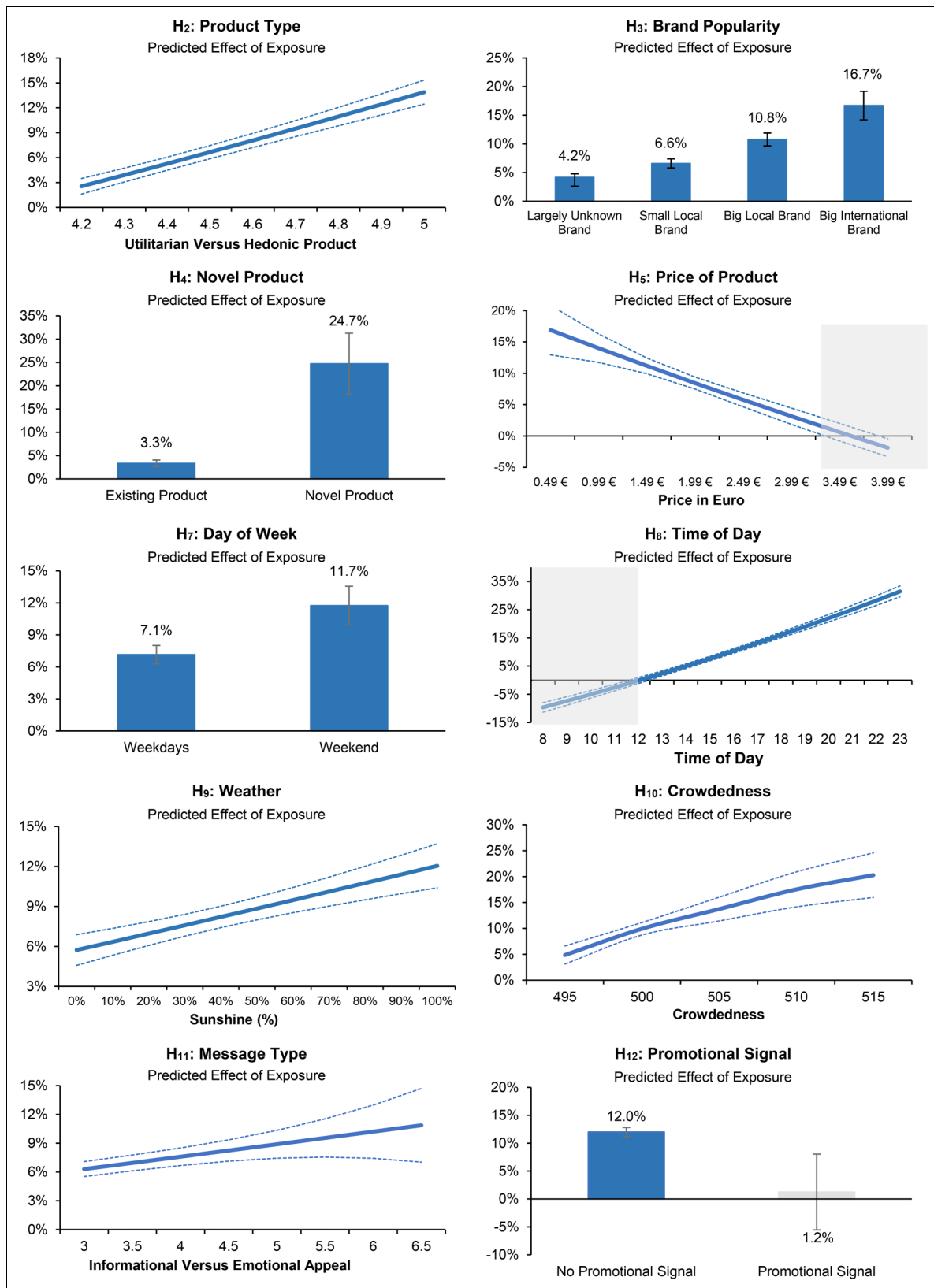


Figure 5. Visualization of Moderating Effects.

Notes: Shaded areas indicate predicted effect where the 95% confidence intervals include zero. We focused on the focal interaction and kept all variables at mean when calculating the results for this figure with the exception of price, which was at its median.

products, in support of the effectiveness of digital signage. However, they cannot address several managerial questions related to the placement of digital signage and its potential effects on spending, product and brand switching, and purchase acceleration. Therefore, we address the following research questions in further analyses:

- Does the placement of digital signage, relative to the featured products, influence its effectiveness?
- Do exposed shoppers spend more (or less) on the featured products than shoppers not exposed when they make purchases?
- How does exposure influence switching between the featured products and other products of the same brands, as well as switching between the featured products and competitive products from other brands?
- Does exposure lead to purchase acceleration (i.e., stockpiling) of featured products?

Placement of Digital Signage

Previous research summarized in Table 1 found inconclusive placement effects. The ads in our study appear randomly on all screens, regardless of their location, so screen placement should not affect the observed results. Nevertheless, to address the contradicting prior findings, we retrieved digital signage placement data for 183 campaigns (Web Appendix M).¹¹ We identify a negative interaction effect between distance to the screen and exposure: The average distance of featured products from screens is 30 meters (98.4 feet), and the odds ratios of the logit model indicate that for every 10-meter (32.8 feet) increase in the proximity of a featured product to the screen, the effect of exposure increases by 2%. No other interaction effects are affected when we include distance to the screen though, indicating that the screen randomization worked and that our findings are robust regarding the placement of digital signage.

Spending Conditional on Purchase

In interviews, manufacturing brand representatives indicated that they mainly employ digital signage to attract purchases from shoppers who otherwise would not purchase, but it also might be interesting to determine the effect of digital signage on purchase quantity for the 311,251 shoppers who make at least one purchase of the focal products. As the results in Web Appendix N reveal, we find no effect of exposure on spending ($\beta = .001, p = .817$), in line with the missing spending effect of digital signage reported by Nanni and Ordanini (2024). Exposed shoppers purchase the focal products but not more of those focal products. This is in line with the finding that novel products benefit much more from digital signage than existing products.

Brand Switching and Product Switching

Previous research has decomposed the effect of price discounts into primary demand effects for the discounted brand—including increased consumption, product switching within the brand, and temporal shifts, which we discuss next—versus secondary demand effects for nondiscounted brands (Gupta 1988; Van Heerde, Leeflang, and Wittink 2004). To the best of our knowledge, no such decomposition has been undertaken for in-store advertising. We retrieve data about the effects of digital signage on the focal products, other products of the same brand, and competitive products from 34 campaigns to examine such potential brand switching and product switching, as detailed in Web Appendix O.¹² Our findings suggest three conclusions. First, digital signage at the POS creates original demand for the focal products (increased purchase probability of 10.1%), making it a desirable in-store advertising tool from a product manager's perspective. Second, digital signage does not evoke any product switching within the same brand but fosters brand switching to the focal brand. Shoppers exposed to an ad for specific products exhibit a higher probability for purchasing at least one of the other products of the same brand (increase of 8.7%) and a lower probability for purchasing at least one product sold by competing brands (decrease of 12.5%). This evidence indicates that digital signage is desirable from a brand manager's perspective. Third, digital signage for particular products has positive spillover effects on the overall category purchase probability (increase of 14.8%), so the use of digital signage is also desirable from a retailer's perspective.

Purchase Acceleration and Stockpiling

We could not track shoppers over time, so we requested additional data from the digital signage provider to consider the possibility of purchase acceleration, as detailed in Web Appendix P. With a quasi-experimental methodology, we compare 16 stores with and without digital signage over a total of 42 weeks to uncover potential purchase acceleration effects evoked by digital signage for two popular stockpiling products. For the immediate effect of digital signage, we find positive effects for both campaigns (increases of 28.8% and 7.1%), indicating that the presence of digital signage increases the average purchase probability for all shoppers, compared with control stores. We thus affirm the robustness of the positive exposure effect. Regarding the potential purchase acceleration effect, we find no effects for both campaigns, indicating that digital signage does not lead to purchase acceleration or stockpiling.

¹¹ The cooperating company made a change to its database, such that we could not retrieve this information for all campaigns in our sample.

¹² We relied on the manufacturing brands to obtain GTINs for the product featured in the ad, other products of the same brand, and competitive products, because the categories provided by the retailer did not support such detailed analyses. Unfortunately, most manufacturing brands were only interested in the effect on their focal product.

Discussion

Contributions to Literature

The growth of in-store retail media, together with retailers' increasing awareness that they can monetize contacts with consumers at the physical POS, emphasize the need for a better understanding of digital signage. With this large-scale study, we identify in detail how exposure to digital signage affects purchase behavior at the POS. Using the two-step process of attention and appraisal from Inman, Winer, and Ferraro (2009), we theorize why digital signage works: Digital signage (1) is located in highly frequented aisles in a visual area that captures a lot of attention and provides 5–15 seconds of exposure, (2) is activated when shoppers approach, which triggers attention because the content starts playing and does not just endlessly repeat, (3) features videos that elicit focal attention with moving elements, and (4) complements the visual cues with audio, which amplifies the effects of visual features at the POS. Building on self-control lens, dual process theories, circadian rhythm, and experiential shopping, we specify several moderators of these effects. We test our predictions with a rich dataset that encompasses 237 field experiments, involving 30 million participants and a diverse range of products and ad campaigns. We examine whether digital signage is effective for promoting products at the POS, for which products digital signage is best suited, when digital signage should be used, and how digital signage can be leveraged most effectively. We structure our discussion accordingly.

Should digital signage be used to promote products at the point of sale? With a novel method that enables us to attribute ad exposures to individual product purchases across all 237 campaigns, we determine that exposure to a digital signage advertisement at the POS increases purchase probability by 8.1%. Thus, digital signage proves to be an effective tool at the POS that creates original demand for the focal products. Shoppers exposed to ads for specific products exhibit a higher purchase probability for other products from the same brand, a lower purchase probability for competitive products, and a higher purchase probability for the overall category. Moreover, digital signage does not lead to purchase acceleration or stockpiling, in contrast with price discounts (Van Heerde, Leeflang, and Wittink 2004). Whereas price discounts urge shoppers to purchase higher quantities, due to their inherently limited availability, digital signage has no such effects, because it offers no discounts. Digital signage also does not affect the amount of spending on featured products among shoppers who purchase, in line with Wertenbroch's (1998) discussion of the trade-off between self-control failure and purchase quantity rationing. As we find, exposed shoppers purchase, but they do not purchase more.

For which products should digital signage be used? The effects of digital signage vary with the product. Hedonic products, products from popular brands, novel products, and lower-priced products benefit more from digital signage. In contrast, digital signage benefits utilitarian products less; these purchases are

often preplanned by shoppers and less likely to be impulsive (Ramanathan and Menon 2006). Similarly, shoppers' self-control appears to be higher for less popular brands as well as existing and expensive products. We find no interplay with discounts, which is not entirely surprising, considering the mixed effects reported in studies of interactions between price cuts and in-store advertising (Zhang 2006). It confirms that digital signage works, irrespective of price cuts and discounts.

When should digital signage be used? The effects of digital signage vary with the day of the week, time of the day, weather, and store crowdedness. These effects are stronger on Saturdays and increase over the course of the day, with the highest effects in the evening, although we also observe a notable peak at 8 a.m. when the store opens. These findings suggest that being busy and tired of making decisions decreases self-control (Kim, Wadhwa, and Chattopadhyay 2019). Digital signage is also more effective in better weather and when the store is crowded, suggesting that in these conditions, shoppers' self-control is lower.

How should digital signage be used? The appeal type and presence of promotional signals inform the effects of digital signage. They are greater with emotional rather than informational appeals, perhaps because the former disrupt shoppers' self-control (Pham 2007). Nonpromotional content increases the effect of digital signage, in line with Grewal et al.'s (2023) findings that inspirational content is more effective than deal-oriented content for in-store advertising. Perhaps such content activates shoppers' inspiration, which in turn lowers their self-control. This further suggests that digital signage may be more effective for shoppers who are innovative and interested in trying new products. These shoppers are very different from deal seekers who generally adhere more strictly to their shopping plans (Bellenger and Korgaonkar 1980). Moreover, actual price cuts ($r = -.197$) and promotional signals ($r = -.107$) are used less often for novel products. When established products are discounted or promoted, traditional signs may actually be more effective than digital signage.

Collectively, these insights provide novel evidence pertaining to retail media and the effects of in-store advertising. To the best of our knowledge, this study is the first to gather extensive field data to determine the effectiveness of digital signage for the manufacturing brands that pay for the ads. By analyzing 237 separate campaigns, we determine which product, timing, and campaign features are best suited for digital signage. This study quantifies the extent to which the effectiveness of the campaigns differs, which is particularly useful for this relatively new advertising channel, because it reveals the ranges of possible outcomes that marketers can expect. In addition, advertising effects tend to be small, and advertising field experiments are often statistically underpowered (Lewis and Rao 2015). By pooling data from multiple campaigns, we simultaneously consider existing moderators and uncover previously overlooked ones related to the digital signage effect. In turn, we establish several new empirical generalizations about the outcomes of

Table 5. Implications and Research Directions.

Research Question	Implications	Research Directions
Should digital signage be used to promote products at the point of sale?	■ On average, exposure to digital signage increases the purchase probability of the featured product by 8.1% ■ Exposed shoppers do not purchase more but more exposed shoppers purchase. ■ Positive spillover effects on other products from the same brand and the overall category, negative effects on competitive products. ■ No purchase acceleration and stockpiling effects.	■ Further research should combine exposure to digital signage with loyalty card data and explore the effect on long-term outcomes such as brand preferences. ■ Research in a country with lower privacy standards should identify bystanders and determine the treatment intensity variation of the effect (e.g., capture the effect of actual exposure and duration of attention). ■ Future research should examine the effect of digital signage on shoppers using baskets. ■ The present study focuses on supermarkets. Further research should explore the effect of digital signage in other types of physical stores.
For which products should digital signage be used?	■ The more hedonic the product, the stronger the effect from digital signage. ■ The effect from digital signage is stronger for more popular brands. ■ The effect from digital signage is stronger for novel products. ■ The effect from digital signage is stronger for lower-priced products. ■ Price cuts do not interact with the effect of digital signage.	■ The present study focuses on products only. Further research should explore the effects of digital signage on general message effectiveness. ■ Featured products were all available in the store. Further research should explore whether digital signage might backfire if products are out of stock or not directly available at the POS. ■ Future research should explore the interplay of digital signage and other in-store marketing tools at the POS, such as endcaps.
When should digital signage be used?	■ Digital signage is more effective on weekends. ■ The effect of digital signage increases over the day with highest effects in the evening. ■ Digital signage is more effective with better weather (i.e., more sunshine, less rain). ■ Higher crowdedness increases the effect of digital signage.	■ The present study shows a higher effect on Tuesdays, where the weekly product flyer is distributed. Further research should explore whether responses to other in-store advertising are also affected by the weekly product flyer. ■ The present study indicates an increase in effectiveness in the early morning. Further research should explore whether responses to other in-store advertising also are higher at this time. ■ Research should explore the role of in-store temperature in altering the responses to digital signage.
How should digital signage be used?	■ The effect of digital signage is greater with emotional messages compared with informational messages. ■ Promotional signals decrease the effect of digital signage.	■ The present study focuses only on selected campaign features. Further research could explore additional features of ads, such as humor, the presence of celebrities, or the facial features of humans. ■ Digital signage in the present study does not optimize the presentation of ads. Further research should use optimization algorithms based on our findings and additional insights (e.g., type of shopper) to make digital signage more efficient.

digital signage at the POS. Finally, we test the theoretical assumptions of the two-step attention and appraisal process (Inman, Winer, and Ferraro 2009) by exploiting a new distinctive technology that stimulates shoppers' attention at the POS. In so doing, we show that some moderators behave differently in our large study than what prior research on digital signage has demonstrated in studies with smaller samples. Consequently, we shed new light on some mixed effects from previous studies on some moderators, as we summarize in Table 4.

Managerial Implications

This research offers timely insights for brand manufacturers and retailers engaged in digital signage by providing concrete evidence about the outcomes they can expect from in-store advertising, as well as recommendations related to features that alter its effectiveness. We provide these implications, along with some research directions, in Table 5. Digital signage appears to be an effective in-store advertising tool to increase the

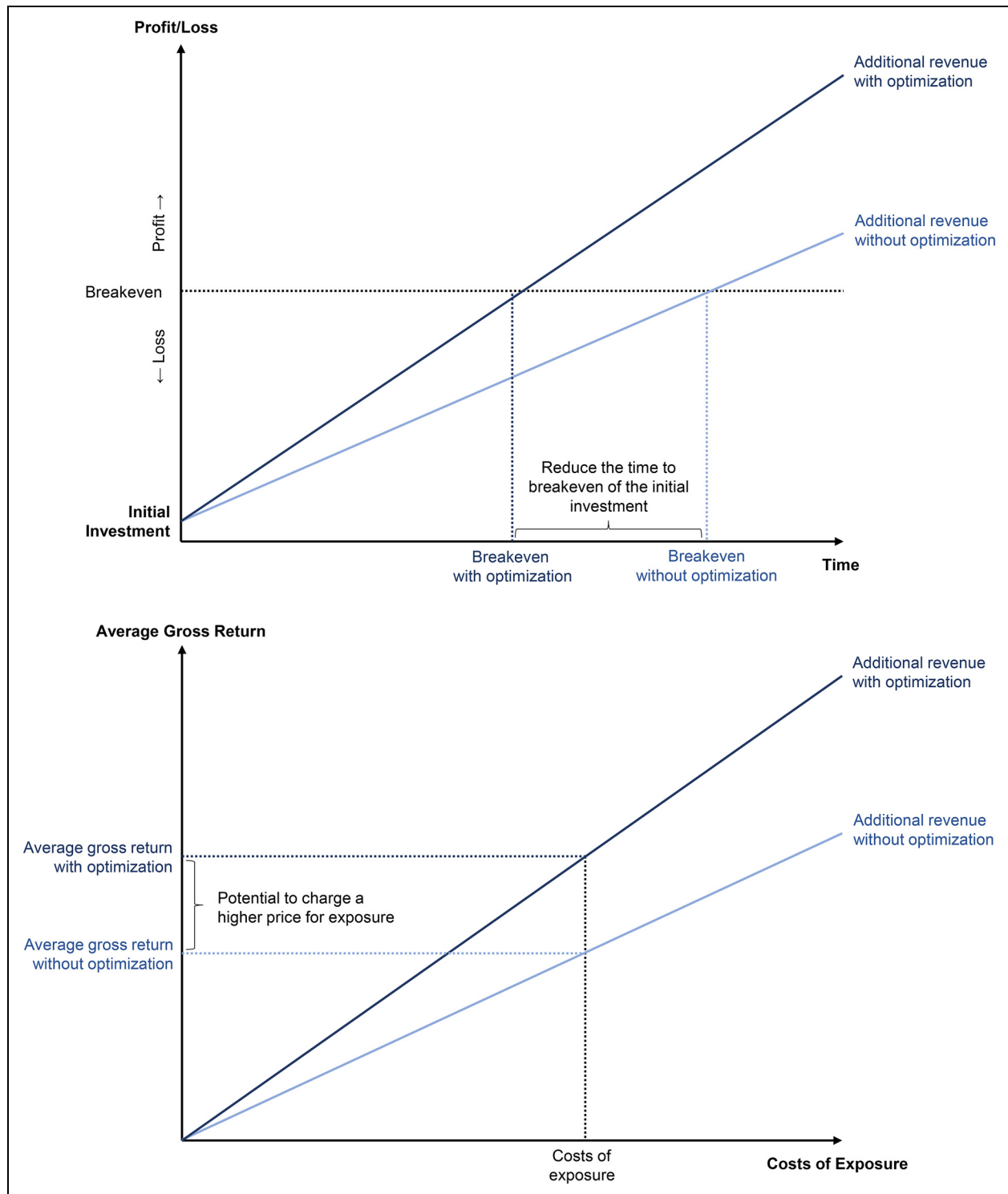


Figure 6. Optimization Effects for Brand Manufacturers and Retailers.

Notes: The value of digital signage is calculated in Web Appendix Q.

purchase probability of featured products, but its effectiveness varies with the product, timing, and campaign. Managers can take advantage of digital signage at the POS and our findings

in diverse retail environments by installing digital screens and connecting impressions to specific ads with purchase behavior. While the connection means may need to be adapted for

different retail formats—using shopping baskets, mobile phone tracking, or face recognition instead of shopping carts—the general logic remains the same: Once it is possible to connect the different data sources, managers can measure and alter their campaigns to maximize effectiveness. To provide actionable insights, we use our results to define the value of digital signage for all stakeholders: brand manufacturers, retailers, and digital signage providers (see Web Appendix Q).¹³

Implications for brand manufacturers. For brand manufacturers, digital signage has positive effects on the featured products and their other branded products. Using these effects, we can calculate advertising elasticity as the percentage change in a brand's sales due to a 1% change in the brand's digital signage investment. We find an elasticity of .18 for digital signage; 50% greater than the empirical generalizations of short-term brand advertising elasticities equal to .12 reported by Hanssens (2015) and Sethuraman, Tellis, and Briesch (2011). Proximity to the POS and the unique features of digital signage likely induce these higher elasticities. Considering the costs of exposure (i.e., how much a brand manufacturer pays for 1,000 exposures) and additional sales minus the retailer's markup, we estimate that a brand manufacturer would earn an average gross return on investments in digital signage of 21%.

Implications for retailers. For retailers, digital signage requires investments in the digital screens, RFID readers, RFID tags in shopping carts, and IT infrastructure. The retailer in our study equipped each store with five digital screens, five RFID readers at the screens, a RFID reader at every cashier, and RFID tags in all shopping carts. To recoup these investments, the retailer needs the additional revenue from the average gross profit margin of around 3% on additional purchases (Repko 2023; Wilson 2023) and the advertising revenue from the brand manufacturers (i.e., the money the retailer receives per 1,000 exposures). Considering the ongoing costs of the system, the digital signage installation in our study would break even for the retailer after approximately one to two years, depending on the percentage of campaigns for its own brand and for manufacturing brands, and provide additional profit afterwards. Our data further suggest that 87.7% of the additional revenue stems from digital signage and only 12.3% from the additional sales, confirming the value of digital signage. These insights can be used by retailers to determine how much they charge brand manufacturers for in-store advertising with digital signage and to develop their pricing and price optimization models.

Implications for digital signage providers. Advertising delivery through digital signage has not been optimized yet. During our study period, the digital signage system did not use any targeting, nor did any other targeting or optimization efforts take place. This

scenario benefited our effort to identify causal effects, but it also indicates that the vast potential for optimization has not been tapped. The digital signage provider we collaborated with plans to leverage our findings to target shoppers and optimize the effectiveness of its digital signage. Increasing the effectiveness of digital signage will enhance the average gross return for brand manufacturers' expenditures, allow the retailer to charge a higher price for exposures to digital signage, and shorten the time until investments in digital signage pay off, as displayed in Figure 6. Thus, all relevant stakeholders in Figure 2 would benefit from optimization effects.

Limitations and Further Research

Continued research should address the limitations and expand the scope of the present research. The digital signage system we studied fully complies with the most stringent privacy requirements, such that we could not identify individual shoppers. Continued research should strive to account for individual differences in self-regulation or add loyalty card data to explore the effects on acquisition and retention. Our findings of a positive interaction effect of product novelty and a negative interaction with the wearout effect offer initial evidence that digital signage might work better for customer acquisition than retention. We also could not identify bystanders; that is, shoppers who did not trigger the ad but were (partially) exposed to it. We assigned these shoppers to the control group, which leads to more conservative estimates. In addition, we could not examine treatment intensity variations, such as exposure duration or shoppers' distance from the digital signage. Research in a country with different privacy standards might attempt to identify bystanders and determine such treatment intensity effects.

We investigated many moderators in our study; considering the multiple testing problem, we recommend treating the findings with care, despite the many robustness tests we conducted. Because the RFID technology relies on shopping carts, we had to exclude all shoppers without carts, but shoppers with carts could differ systematically from shoppers who use baskets instead. Our data collection took place in retail stores in a western European country and focused on featured products. The effects of digital signage might differ in different settings, and we encourage future research to examine digital signage in other types of stores and other countries to generalize our results. Going beyond the focus of our study, future research might further explore whether our results generalize to display and banner ads in online retail settings.

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¹³ We sometimes use industry averages rather than actual values in the reported calculations, reflecting the nondisclosure agreements with the digital signage provider, brand manufacturers, and retailer.

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