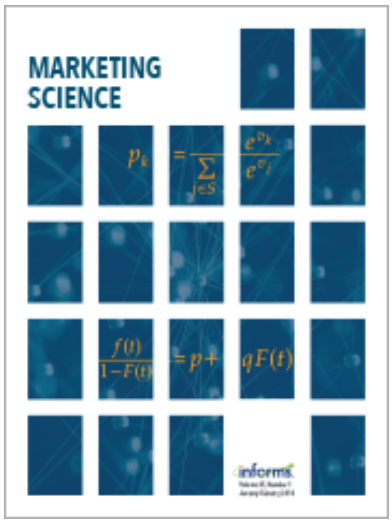

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Prominent Attributes Under Limited Attention

Yi Zhu,[a] **Anthony Dukes**[b]

[a] Carlson School of Management, University of Minnesota, Minneapolis, Minnesota 55455; [b] Marshall School of Business, University of Southern California, Los Angeles, California 90089

Contact: yizhu@umn.edu, http://orcid.org/0000-0002-7969-1160 (YZ); dukes@marshall.usc.edu, http://orcid.org/0000-0003-2699-8019 (AD)

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Abstract. Evidence shows that marketers can direct consumers' limited attention to specific product attributes by making them "prominent." This research asks: How should firms decide which attribute to make prominent in competitive environments? A key feature of this setting is that consumers' preferences are context-dependent and that a firm's choice of an attribute affects the evaluation of all products in the category. We develop a model in which firms selectively promote one of two attributes (e.g., image or performance) before competing in price. We find when consumers evaluate both attributes, perceived differentiation within an attribute can become diluted; we call this the *dilution effect*. This implies that making the same attribute prominent can arise in equilibrium. Only if there is a sufficient quality advantage in an attribute do we find equilibria with firms making different attributes prominent. We also show how the dilution effect can be a disincentive for investments in quality improvements.

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Keywords: prominent attributes • limited consumer attention • dilution effect • context-dependent preferences • competitive strategies

1. Introduction

Consumers are often constrained in the amount of attention they can devote to evaluating products. Because of this, some marketing managers suggest limiting the number of attributes to emphasize to consumers.[1] Emphasizing too many attributes may dilute a consumer's focus such that she pays less attention to any particular one. Evidence from psychology literature further indicates that one's attention can be directed to a certain aspect of a choice environment so that it receives more weight in decision making (reviewed in Taylor and Thompson 1982). In light of this, marketers try to direct consumer's limited attention with the hope of affecting which attribute she considers important, or *prominent*, in purchase situations (e.g., Wright and Rip 1980, Gardner 1983, MacKenzie 1986, and Jiang and Punj 2010). MacKenzie (1986), for instance, shows that manipulations of the prominence of a particular attribute for watches in print ads directly affected the subjects' attention to that attribute and the subsequent importance they assigned to it. Yet the question remains: Which product attribute should the marketer emphasize?

Determining the attribute to emphasize may seem as simple as assessing which attribute best accentuates the value of the product. Yet some managers suggest that selecting which attribute to emphasize may be particularly challenging in a competitive context. It might be tempting to argue that competitors will emphasize different attributes to maintain product differentiation. Yet the managers we interviewed suggested that in some circumstances a marketer may want to emphasize the same product attribute as a competitor. This research provides a possible rationale for this strategy by examining the interactions among competing firms in their selection of which attributes to communicate to consumers with attention constraints.

To illustrate the challenges of limited attention in a competitive setting, consider a consumer deciding which craft beer to buy. She faces a large number of beer options but recalls a brand label from Craft Beer X that emphasizes where it is brewed. As she considers the brewing location, she notices that a different brand, Craft Beer Y, is brewed in her hometown, an aspect sufficiently important to her that she is ready to choose it. Yet she sees advertisements from Brand Y, and notices the emphasis on a funky and party-going lifestyle, which is quite different from her self-identity. Because she had not previously paid any attention to the lifestyle attribute, she reconsiders Brand X and notices its emphasis on an outdoor-adventure lifestyle. Before seeing Brand Y's advertisements, her choice was clearly Brand Y. Now, overall, she is relatively indifferent between Brands X and Y, and the beers appear less differentiated than when she only considered the brewing location. This reduction in differentiation is not due

to any negative correlation between the two attributes. Rather, as we show, it is a general result of the fact that, if a consumer finds a product more attractive in one attribute (brewing location), then the inclusion of the second attribute (lifestyle) will reduce, on average, its relative attractiveness when the consumer splits her attention.

The above example illustrates the strategic nuances of choosing which attribute to make prominent in a competitive context because (i) the firm's decision affects consumer's preferences for all products, including rivals', and (ii) each firm can non-cooperatively try to influence the consumer's attention to the same attribute or distinct attributes. These competitive interactions take on additional significance considering that the marketer typically faces bandwidth constraints,[2] which limits the number of attributes that can be communicated to consumers. The focus of this research, therefore, is on the strategic interactions among competing marketers in their decisions about which attribute to make prominent.

The beer illustration also conveys the fundamental mechanism behind our findings: When consumers have limited attention, any perceived differentiation within a single attribute can become diluted across multiple attributes; we call this the dilution effect. We find that a firm may emphasize the same attribute as its rival to avoid the dilution effect and maintain product differentiation. Marketing the same attribute as a competitor is a strategy documented in the beer industry. Schnell and Reese (2003) and Hede and Watne (2013), for instance, argue that the branding, labeling, and packaging of craft beers commonly emphasize the attribute of brewing location. By emphasizing their brewing location, brewers can effectively become more distinct from their competitors (Tierney 2014). This is also consistent with the practice of listing beers by name and brewing location only, as is done at many bars and restaurants. See Figures 1–3 for examples of this marketing strategy. (See the online appendix for additional examples of these practices.)

The dilution effect is fundamentally linked to limitations in consumer's attention. When consumers have limited attention, they may not always evaluate and compare alternatives on all attributes (Russo and Dosher 1983, Bettman et al. 1998). For some purchases consumers may initially be unaware of all of the relevant attributes. Furthermore, the attributes the consumer pays attention to can be affected by the market environment (Johnson et al. 1988, Tversky et al. 1988, Shavitt and Fazio 1991). As mentioned above, marketers may try to influence the market environment through advertisements, packaging or branding so that a consumer's attention is drawn to a specific attribute. If firms emphasize the same attribute, then a consumer evaluates products only on that attribute. If, however, firms emphasize different attributes, limited attention implies that the consumer splits her attention across multiple attributes. In this latter case, a consumer's attention is diluted. As we show, this effect has implications for how a consumer compares available alternatives, which affects the subsequent price competition. That is, by making the same attribute prominent, competing firms can set higher prices.

Our findings are consistent with the principle of product differentiation: Competing firms prefer that consumers perceive products as maximally differentiated. However, one might intuit from this classic principle that competing firms should always emphasize the distinct attribute in which they excel. An implication of limited attention is that perceived differentiation may be largest when the consumer considers fewer attributes. In fact, even if one firm has a quality advantage in one attribute, it may be better to emphasize the same attribute as its competitor to avoid the risk of reducing perceived product differentiation. Only

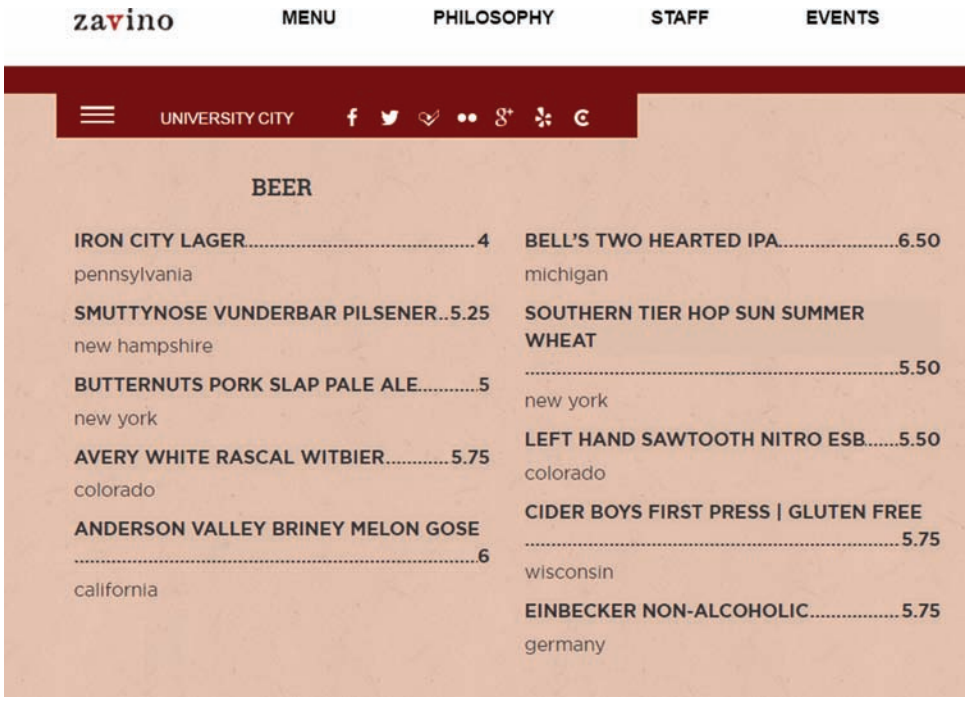
Figure 1. (Color online) Examples of Beer Labeling and Packaging (Anchor Brewery, California)

Figure 2. (Color online) Examples of Breweries' Logos with Location Elements[a]

[a]First four brands are owned and distributed by Anheuser-Busch. Tsingtao Beer is brewed in Tsingtao (Qingdao), China.

if a firm's quality advantage in a particular attribute is sufficient should it emphasize a different attribute than its competitor. Our survey of marketing managers echoes the idea that emphasizing the same attribute as a competitor is, in some instances, the best strategy when consumers have limited attention. This is not restricted to the marketing of craft beer (i.e., the location attribute). Marketing executives at major companies expressed this approach for microwave popcorn (lifestyle attribute, e.g., movie night at home), health insurance (medical specialty attribute, e.g., doctor network), and even in the market for industrial cleaning supplies (cleaning application attribute, e.g., industrial or home use). To assess whether the dilution effect might be a factor in consumer decisions, we informally polled 250 consumers about their perceptions of automobile choices under different contexts. Over 62% found that automobile choices (e.g., Ford versus Volvo) seem more similar when compared on many attributes (e.g., safety, appearance, performance)

Figure 3. (Color online) Craft Beer Menu (Zavino Restaurant, Philadelphia)



than when compared on a single attribute (e.g., performance). (See the online appendix for more details of this survey.)

These results arise from a model in which competitive firms selectively choose an attribute to make prominent. We define an *attribute* as any aspect of a product category that the consumer regards as relevant for determining the level of utility. An attribute need not be a physical feature of the products in that category. Rather, we assume it is a mutually accepted component of the consumer's utility. For example, a consumer may assess the expected enjoyment of an untried beer based on the attribute of brewing location or lifestyle, or both. We further assume that any attribute has a horizontal component. In the beer example, the brewing location and lifestyle attributes each have idiosyncratic aspects for which only the consumer herself knows her preference. Furthermore, an attribute may have a vertical component that all consumers value in the same way. Continuing with the beer example, consumers may prefer beer from a location that is famous for its high brewing standards (such as beer from Germany).

There are two firms, each with two attributes (e.g., brewing location and lifestyle). We assume each firm announces exactly one as its prominent attribute. For example, firms will highlight their chosen attribute via advertising, promotion materials or packaging. Consumers evaluate products by examining random fit parameters for the prominent attributes. We first study the case of symmetric firms when attributes are only horizontally differentiated. In this case, firms choose the same attribute to make prominent in equilibrium. If firms emphasize the same attribute, they ensure that consumers regard that single attribute as the most important. Given idiosyncratic tastes on that attribute, the consumer purchases the product that is most satisfying on it. However, if firms emphasize different attributes, the consumer evaluates products on multiple attributes. If the consumer's attention is limited, then she is forced to split her attention across those attributes, which attenuates her relative appreciation of any single attribute. With significant likelihood, the consumer will find that a firm who dominates on one attribute will dominate to a lesser degree on both. On average, the consumer will view the products as relatively less differentiated. Under the dilution effect, firms are induced to price more competitively.

We then consider the case in which each firm has a quality advantage in exactly one attribute. In this case, firms will make the same attribute prominent in equilibrium if the quality advantage is not too large. That is, one of the firms actually makes its inferior attribute prominent to avoid the dilution effect. Only if the quality advantage is sufficiently large will firms benefit from making their best attribute prominent.

For the above results, we assume that firms decide about prominent attributes for exogenous quality advantages. Yet, in practice, firms may want to build a quality advantage in an attribute after establishing it as prominent. For instance, Volvo is known for its safe performance, thus the manufacturer continues to invest in safety to maintain its competitive performance advantage. Conversely, a firm's decision to invest in quality may be affected by subsequent competition in attribute prominence. In light of the interplay between quality investment and prominent attributes, we extend the model to the case of endogenous quality. Regardless of the timing of quality investments, we find that limited attention and the implied dilution effect can deter such investments.

This paper connects to two broad literatures devoted to consumers' context-dependent preferences. First, as noted above, the consumer psychology literature has long suggested that consumers tend to focus more on an attribute when that attribute is emphasized in a choice context (Tversky et al. 1988 and Shavitt and Fazio 1991), which can be affected by the marketer (Wright and Rip 1980, Gardner 1983, and MacKenzie 1986). A more recent stream of work in economics formalizes the relationship between attention and choice when consumers have context-dependent preferences (Kőszegi and Szeidl 2013, Bordolo et al. 2013). To our knowledge, however, none of this research formally considers the equilibrium interactions with firms when consumers' limited attention is directed by marketing. Second, there is literature from economics and marketing that examines the firm-side implications of context-dependent preferences in an equilibrium framework (Wernerfelt 1995, Kamenica 2008, and Guo and Zhang 2012). Our work, unlike all of the above research, has two important distinctions. First, we concentrate on the case of competitive firms, each of whom contributes to the consumer's choice context. A firm needs to anticipate the other firm's attribute strategy when deciding the optimal prominent attribute, even though it may be suboptimal in monopoly. Second, we model a consumer's context-dependent preferences at the product category level instead of individual products. Specifically, when one firm makes an attribute prominent, the attribute is prominent for the consumer on all products in that category. This implies interesting strategic interactions which, to our knowledge, have not yet been examined.

There is a number of related works that study firms' disclosure policies and advertising content strategies. For instance, Anderson and Renault (2006), Johnson and Myatt (2006), Kuksov and Lin (2010), Bar-Isaac et al. (2012), and Branco et al. (2016) examine a firm's decision about how much "match" information to reveal to potential customers. That work considers content for consumers that is specifically related to the

product(s) it sells. Firms in our setting can be interpreted along the same lines, revealing match values to consumers on one attribute. The key distinction, however, is that in our model firm's disclosure applies to the attribute match values for *all* products in the category, not the disclosing firm only. This implies that a firm's advertising strategy affects how consumers evaluate competitive firms as well as its own.[3]

A related stream of research studies firms' communication strategies under bandwidth constraints. Like our paper, Bhardwaj et al. (2008) and Mayzlin and Shin (2011) start with the premise that a firm cannot communicate all aspects of its product to consumers, as is typically assumed in models of informative advertising (Butters 1977, Grossman and Shapiro 1984). Bhardwaj et al. (2008) compares "seller-initiated" versus "buyer-initiated" information revelation to identify the subset of attributes about which the buyer can learn. Mayzlin and Shin (2011) study a firm's decision about which, if any, product attribute to present to consumers. In both papers, there is asymmetric information about the product's overall quality and the firm's decision about what information to reveal is governed by its impact on consumer beliefs about quality (via signaling). By contrast, in our work there is no uncertainty about quality and the firm's decision about which attribute to announce is determined by competitive interactions when consumer's attention is limited.

The remainder of the paper is structured as follows. In the next section, we present the basic framework of consumer preferences under limited attention and the corresponding purchase rule. In Section 3, we illustrate the dilution effect as the key mechanism and explore several natural departures to understand its generalizations and limitations. In Section 4, we examine the equilibrium choices of attribute prominence when firms have exogenous quality advantages. In Section 5, we extend our model to allow firms to endogenously decide their quality. Section 6 concludes with an overview and discussion of future research. Proofs of technical results are provided in the appendix. See the online appendix for additional technical details and supplemental materials.

2. The Model

There are two firms, indexed as $j = 1, 2$, each of which produces a product defined by two attributes $k = A, B$. Each attribute has a firm-specific quality component q_{jk}. Any firm can have a quality advantage in one or both attributes. For simplicity, we assume that there exist *only* two quality levels in each attribute that firms may produce, i.e., low quality q^L and high quality $q^H > q^L$. We also normalize the marginal production cost for both products to be zero. The mass of consumers is normalized to one and each consumer has unitary demand. We first assume that the quality level is exogenously given; this allows us to abstract away from the firms' quality decisions. In Section 5, we expand our analysis of prominent attributes when firms make endogenous quality decisions.

The timing of the model is as follows. First, each firm decides its prominent attribute. Second, after observing each other's prominent attribute choice, firms choose their product prices. Third, consumers form their preferences on prominent attribute(s), which are determined by firm's announcement strategies. Finally, consumers evaluate products and purchase one product from a firm.

2.1. Consumer Utility from Evaluation

Each consumer has an idiosyncratic match value for each attribute of each product. If the consumer knows of one attribute she evaluates both products on that attribute only. If both attributes are prominent, the consumer evaluates products on both. In this way, we do not explicitly model the consumer's search process or the decision on which attributes or products to evaluate; this allows us to focus on firms' competitive strategies.

Suppose a consumer has evaluated only attribute k from both products. Her utility of product j based on inspecting attribute k is given by

$$u_{jk} = (V - p_j) + \theta_k(q_{jk} + \nu_k \varepsilon_{jk}), \tag{1}$$

where V is the intrinsic value of the product, q_{jk} is the quality of firm j in attribute k, and $\varepsilon_{jk} \sim N(0,1)$, which captures randomness in consumers' tastes among products on attribute k. The parameter $\varepsilon_{jk} \sim N(0,1)$ is often called the fit or match value that the consumer draws for product j on attribute k. Normally distributed match values have a convenient additive property that is useful in defining preferences when the consumer evaluates both attributes. We assume the distributions of random match value from two attributes are independent.[4] The parameter ν_k captures the degree of heterogeneity of consumer tastes in attribute k. The parameters V, p_j, q_{jk}, and ν_k are common to all consumers whereas the component ε_{jk} is idiosyncratic to the individual consumer. The factor θ_k is the weight parameter for attribute k depending on firms' prominent attribute decisions.

When consumers evaluate both attributes, we assume the total utility is additive on the attribute-dependent utility components. In particular, for a consumer evaluating product j on both attributes, her utility is given by

$$u_{jAB} = (V - p_j) + \theta_A q_{jA} + \theta_B q_{jB} + \nu_{AB} \varepsilon_{jAB}, \tag{2}$$

where $\nu_{AB}\varepsilon_{jAB} = \theta_A \nu_A \varepsilon_{jA} + \theta_B \nu_B \varepsilon_{jB}$. Since $\nu_k \varepsilon_{jk} \sim N(0, \nu_k^2)$, $k = A, B$ and independent, the random fit term

$\nu_{AB}\varepsilon_{jAB} \sim N(0, \nu_{AB}^2)$, where $\varepsilon_{jAB} \sim N(0,1)$ and $\nu_{AB} = \sqrt{\theta_A^2\nu_A^2 + \theta_B^2\nu_B^2}$.

We now discuss the influence of firms' decisions on the value of the weight parameters, θ_A and θ_B. These weight parameters reflect the amount of attention the consumer pays to an attribute.[5] Our approach to modeling consumer's attention is akin to Kőszegi and Szeidl (2013) and Bordolo et al. (2013). Firms' announcements do not affect consumers' total attention level, which we normalize to be 1, without loss of generality (in Section 3.3 we explore the possibility that consumers' total attention may depend on firms' announcement). We also assume the weight parameter is completely decided by firms' prominent attribute strategies. Another way to interpret this assumption is that consumers are initially unaware of an attribute, and therefore have no preferences about it until a firm draws attention to it. We make this assumption to capture the influence of firms' marketing activities on consumers' preferences on attributes, which is the key focus of this paper. If both firms make attribute k prominent, consumers treat that attribute as the only important one and will devote all their attention to it. Hence in this case, the weight parameter $\theta_k = 1$. On the other hand, when firms announce different attributes, then consumers treat both attributes as equally important and split their attention equally across both attributes. Therefore, $\theta_A = \theta_B = \frac{1}{2}$: Less attention leads to a lower appreciation of any single attribute. The symmetric split of attention may, at first, seem to be a restrictive assumption. For instance, consumers may have asymmetric preferences over the two attributes, placing more importance on one over another. Our main result holds, however, as long as consumers do not fully ignore an attribute and correspondingly allocate some positive attention to both attributes ($0 < \theta_A = 1 - \theta_B < 1$). Therefore, we assume equal weight on each attribute for simplicity and without loss of generality.

There is no incomplete information in product evaluation; consumers learn the available match values at no cost. However, the weight parameter θ is endogenously decided by firms' strategies in choosing prominent attributes, which is the key feature of the context-dependent preferences in this model. To focus on firm interactions, we do not consider the consumer's economic decision of how to allocate attention.[6]

2.2. Consumer Purchase Decisions and Firms' Market Share

The consumer decides only the product to purchase, which depends on whether she has evaluated one or two of the products' attributes. Specifically, if attribute(s) $k \in \{A, B, AB\}$ is evaluated, then her chosen product is $j^*(k) = \arg\max_j u_{jk}$. Because error terms $\nu_{jk}\varepsilon_{jk}$, $j = 1, 2$, are normally distributed, closed-form choice probabilities are not possible. In this case, equilibrium results are available only by numerical simulation and do not lend themselves to conveying the model's intuition.[7] To surmount this difficulty without compromising any result, we approximate $\nu_k\varepsilon_{jk} \approx_D \mu_k\sigma_{jk}$, where σ_{jk} is distributed as a type-I extreme value and $\mu_k \propto \nu_k$.[8] This permits us to formulate the purchase probability for each firm as a discrete choice logit demand[9] (Anderson et al. 1992), which is derived in the following lemma.

Lemma 1. *If consumers evaluate only one attribute, $k \in \{A, B\}$, then the probability of purchasing from firm $j = 1, 2$ is*

$$s_{1k} = 1 - s_{2k} \approx \frac{e^{(q_{1k}-p_1)/\mu_k}}{e^{(q_{1k}-p_1)/\mu_k} + e^{(q_{2k}-p_2)/\mu_k}},$$

where $\mu_k \propto \nu_k$. (The constant of proportionality is defined in the appendix.)

If consumers evaluate attributes A and B, then the probability of purchasing from firm $j = 1, 2$ is

$$s_{1AB} = 1 - s_{2AB} \approx \frac{e^{(\theta_A q_{1A} + \theta_B q_{1B} - p_1)/\mu_{AB}}}{e^{(\theta_A q_{1A} + \theta_B q_{1B} - p_1)/\mu_{AB}} + e^{(\theta_A q_{2A} + \theta_B q_{2B} - p_2)/\mu_{AB}}},$$

where $\mu_{AB} = \frac{1}{2}\sqrt{\mu_A^2 + \mu_B^2}$.

Because there is no closed form solution of a choice model when the match value is normally distributed, Lemma 1 is a useful technical result. The purchase probabilities expressed in Lemma 1 exhibit the usual properties of the logit demand. In particular, greater variance in the consumer's maximized value of $\nu_k\varepsilon_{jk}$, as measured by μ_k and proportional to ν_k, implies a lower sensitivity to differences in quality and price. Because of the proportional relationship between μ_k and ν_k, henceforth we refer only to the parameter μ_k when discussing the degree of horizontal differentiation within attribute k. With closed-form expressions for choice probabilities at each firm, we can find the equilibrium of the game played by the two firms.

3. The Dilution Effect

3.1. Equilibrium in Prominent Attributes

We can now illustrate the dilution effect using the model described above by solving the prominent attribute decisions of firms in equilibrium.[10] Assume $\mu_A = \mu_B = \mu$, for symmetry[11] and let $\Delta_k \equiv q_{1k} - q_{2k}$ be the quality advantage for firm 1 in attribute $k = A, B$. We start with the benchmark case in which there is no quality differentiation among firms in any attribute, $\Delta_k = 0$. In this case, as demonstrated in Proposition 1, firms make the same attribute prominent in equilibrium. This is a helpful benchmark because it isolates the key mechanism in all of our results on firms' prominent attributes decisions.

Proposition 1. *If $\Delta_k = 0$, $\forall\, k$, then firms choose the same attribute to make prominent in equilibrium.*[12]

To see why announcing the same attribute is an equilibrium, consider a deviation by one firm to announce the other attribute. Such a deviation implies that the consumer evaluates both products on both attributes. Because a consumer's attention is fixed, she splits her attention across both attributes and therefore places less weight on any particular attribute. The variance of the consumer's random match value is reduced as a result: $\text{var}(\mu_{AB}\varepsilon_{jAB}) = \mu^2/2 < \mu^2 = \text{var}(\mu\varepsilon_{jk})$. This implies that equilibrium prices, and corresponding profits, fall for both firms when announcing different attributes: $p_{AB} = \sqrt{2}\mu < 2\mu = p_A = p_B$ and $\pi_{AB} = (\sqrt{2}/2)\mu < \mu = \pi_A = \pi_B$. We call this the *dilution effect*: On average, a reduction in the variance of the match value dilutes perceived firm differentiation by the consumer. To see this another way, suppose a consumer evaluates only attribute A and prefers firm 1 ($u_{1A} > u_{2A}$). Then, it is likely that the strength of her preference for firm 1 will shrink when consumers evaluate both attributes.[13] The dilution effect, therefore, has a downward impact on equilibrium prices. Thus, it is not profitable for a firm to announce an attribute differing from their rival.

3.2. Generalizations and Limitations of the Dilution Effect

To better understand the mechanism driving the dilution effect, and its limitations, we explore several natural departures from the stylized assumptions made above. As we show, some of these assumptions, such as the correlational structure of the random error terms, are not crucial for the existence of the dilution effect. By contrast, the assumption of limited attention is essential.

We revisit Equations (1) and (2) with more generality than assumed in Proposition 1. One aspect we add is a possible correlation between attribute match values. Let $\rho \equiv \text{cov}(\varepsilon_{jA}, \varepsilon_{jB}) \in [-1, 1]$. We will also allow arbitrary attribute weightings θ_k.[14] As suggested above, firms benefit from choosing the same attribute if and only if doing so achieves greater horizontal differentiation than announcing different attributes. In our formulation, one can assess the degree of perceived horizontal differentiation by comparing the variances v_A or v_B with v_{AB}. That is, firms jointly prefer to emphasize attribute k if $v_k > v_{AB}$, or with the transformation in Lemma 1, if

$$\mu_k > \mu_{AB} = \sqrt{\theta_A^2\mu_A^2 + \theta_B^2\mu_B^2 + 2\rho\theta_A\mu_A\theta_B\mu_B}, \qquad (3)$$

which follows from the joint normality of $\{\varepsilon_{jA}, \varepsilon_{jB}\}$. We use condition (3) to assess what fundamental parameter values are required for the dilution effect and how they affect its strength.

Limited Attention. The first observation arising from condition (3) is the importance of limited attention for the dilution effect. To see this, suppose that $\mu_A = \mu_B$, $\theta_A = \theta_B = \theta$, and $\rho = 0$. The condition in (3) simplifies to $\mu_k > \mu_{AB} = \theta\mu_k\sqrt{2}$, which does not hold for $\theta > 1/\sqrt{2}$. For example, suppose consumers are not limited in their attention so that $\theta_A = \theta_B = 1$ when firms announce different attributes. Then there is no dilution effect and (3) does not hold. Correspondingly, the outcome of Proposition 1 is not an equilibrium.

Correlation of Attributes. If a consumer is likely to prefer firm j on, say the performance attribute, then she may also be likely to prefer firm j on the styling attribute. In this case, $\rho > 0$. To study the impact of correlated attribute match values, assume for simplicity, symmetric attribute importance, $\theta_A = \theta_B = 1/2$. (The intuition generalizes for $\theta_A\theta_B \in (0, 1)$ such that $\theta_A = 1 - \theta_B$). In this case condition (3) requires

$$\mu_{AB} = \frac{\sqrt{2}}{2}\mu_k\sqrt{1+\rho} \le \mu_k, \qquad (4)$$

where equality holds if and only if attributes match values are perfectly and positively correlated, $\rho = 1$. When attribute match values are positively correlated, the dilution effect is weakened. Suppose, for instance, only attribute A is evaluated and favors firm 1. If attribute B is evaluated, then the match value ε_{1B} being lower than ε_{2A} is less likely with positive correlation. This can be seen in (4) by the fact that μ_{AB} is increasing in ρ. More intuitively, if the consumer tends to prefer brand 1 over brand 2 because of its performance, then the correlation implies that she is likely to prefer brand 1 on both performance and styling. Recall that without correlation, there is a stronger chance that a comparison on attribute B will lower her overall preference for firm 1.

Interesting, as well, is the case of negative correlation ($\rho < 0$). In this situation, the dilution effect is even more extreme than in the uncorrelated case because it is more likely that evaluation of the second attribute will undermine the preference. For example, suppose a potential student evaluates two universities based on two attributes, i.e., available majors and challenging (and difficult) professors. Negative correlation implies that a university with a desirable major probably has reputable professors who require a challenging workload. A student who compares universities based only on which major she wants will have a clear favorite. Yet, when comparing on both attributes, she will see that professors at universities with a preferred major will assign more work, which undermines her choice based on available majors only. In fact, if these two attributes are perfectly negatively correlated ($\rho = -1$), then the dilution effect is so strong that the two alternatives are perfectly undifferentiated when consumers consider two attributes: $\mu_{AB} = 0$.[15]

Asymmetric Attribute Variance. It is reasonable to wonder about the impact of $\mu_A \neq \mu_B$ on the condition (3) and the existence of the dilution effect. Generally, as long as $\mu_A \approx \mu_B$, then condition (3) continues to hold under limited attention: $\theta_A + \theta_B = 1$. However, in this asymmetric attribute case, firms choosing the attribute with the larger variance will lead to a Pareto superior outcome relative to choosing the attribute with the smaller variance. Specifically, suppose $\mu_A/\mu_B > 1$. Then profits for both firms are larger when they coordinate on attribute A than on attribute B. In fact, the two equilibria of Proposition 1 remain if μ_A/μ_B is not too large. Alternatively, if μ_A/μ_B is sufficiently large, then $\mu_A > \mu_{AB} > \mu_B$, which negates the dilution effect in condition (3). In this case, condition (3) must be modified to $\max\{\mu_k\} > \mu_{AB}$. Furthermore, choosing attribute B is not an optimal strategy because each firm has a unilateral incentive to deviate to attribute A.

Correlation of Firms' Match Values. The assumption of independence of match values across firms can also be relaxed. In such situations, consumers have similar tastes on a particular attribute at both firms. For example, if the consumer enjoys the styling of brand 1, she is likely to enjoy the styling of brand 2. To consider this situation, suppose that for some $k = A, B$, $\mathrm{Cov}(\varepsilon_{1k}, \varepsilon_{2k}) = \tau \in [-1, 1]$. The possibility that $\tau \neq 0$ means that we can no longer use Lemma 1 to approximate choice probabilities; consequently, equilibrium prices and profits are extremely difficult to derive analytically. However, we can directly measure the impact of correlation on the consumer's relative preferences over firms depending on the firms' attribute choices. Specifically, we focus on the impact of τ on the distribution of $u_{1k} - u_{2k} \approx \mu\varepsilon_{1k} - \mu\varepsilon_{2k}$, for $k = A, B$ and AB. We have

$$\mathrm{Var}(u_{1k} - u_{2k}) = \mu^2[\mathrm{Var}(\varepsilon_{1k}) + \mathrm{Var}(\varepsilon_{1k}) - 2\tau] = \mu^2(2 - 2\tau), \tag{5}$$

for $k = A, B$, and

$$\mathrm{Var}(u_{1AB} - u_{2AB}) = \mu^2\mathrm{Var}\left[\tfrac{1}{2}(\varepsilon_{1A} - \varepsilon_{2A}) + \tfrac{1}{2}(\varepsilon_{1B} - \varepsilon_{2B})\right] = \mu^2(1 - \tau). \tag{6}$$

The variance in (5) minus that in (6) measures the impact of firms announcing different attributes relative to announcing the same attribute. Because this difference is positive for any $\tau < 1$, there is strictly less variance in consumer preferences when firms announce both attributes. This implies that, when firms announce different attributes, consumers perceive firms as less differentiated. Limited attention implies that consumers are subject to the dilution effect even when there is a correlation in match values across firms. The strength of the dilution effect, however, declines as this correlation increases. As τ increases, consumers are likely to draw similar match values for both firms on any given attribute. Thus, firms have a lower perceived differentiation independent of the number of attributes they consider. The incremental benefit of forcing the consumer to consider only one attribute is therefore smaller as τ increases. Similar to the case of correlation of attributes, we can see that the dilution effect disappears only if the distributions are perfectly correlated ($\tau = 1$).

Intrinsic Preferences Over Attributes. Finally, we consider the case in which consumers have intrinsic preferences over the different attributes.[16] For instance, consumers may intrinsically judge a product more heavily on attribute A. The extended formulation of (1), which accounts for attribute weighting, is written as $u_{jk} = (V - p_j) + W_k\theta_k(q_{jk} + \nu_k\varepsilon_{jk})$, where $W_A, W_B \geq 0$. Without loss of generality, we assume $W_A \geq W_B$. (See the online appendix for a detailed analysis.) The result confirms the existence of the dilution effect even when consumers have an asymmetric intrinsic preference over attributes. In particular, intrinsic preferences for attributes is not essential for the dilution effect. We extend the analysis to the case in which consumers have heterogeneous preferences over attributes, and show that our results hold under some conditions.

3.3. Attention Expansion and the Dilution Effect

We have maintained the assumption that the level of consumer attention is fixed and independent on firms' attribute announcement. However, it is reasonable to entertain the idea that consumers' supply of attention depends on the number of attributes advertised. For example, if consumers notice firms emphasizing different attributes, then they may want to devote more total attention to evaluating their options (Alter et al. 2007). Devoting more attention, however, comes at the cost of diverted attention to some other activity. In this section, we will allow for this trade-off and explore the strategic interaction of consumers' attention choice with the firms' announcement strategy.

We normalize consumer attention to be 1 when both firms make the same attribute prominent. When firms announce different attributes, however, consumers can expand their total attention. For simplicity, we assume consumers split their attention equally across the two attributes, so that $\theta_A = \theta_B = \theta \in [\frac{1}{2}, 1]$. That is, the total attention the consumer can use to evaluate products when firms announce different attributes is $2\theta \geq 1$. For any given choice $\theta \geq \frac{1}{2}$, the consumer incurs the cost $(a/2)(2\theta - 1)^2$, where $a > 0$ is an exogenous cost parameter. This represents the consumer's opportunity cost of diverting her attention from some other activity.[17] This specification reflects increasing marginal costs. Therefore the consumer's utility function is

$$u_{jAB}(\theta) = (V - p_j) + \theta(q_{jA} + q_{jB}) + \nu_{AB}\varepsilon_{jAB} - \frac{a}{2}(2\theta - 1)^2, \tag{7}$$

where $v_{AB} = \theta\sqrt{v_A^2 + v_B^2}$. For consumers, they need to choose the optimal θ to maximize the expected utility. Let $q_{jA} = q_{jB} = q$, so that we maintain the condition of Proposition 1 of $\Delta_k = 0$, for $k = A, B$. The specification in (7) immediately implies that, when firms announce different attributes, the equilibrium level of consumer attention $\arg\max_\theta E(u_{jAB}) = \theta^* = q/(2a) + \frac{1}{2}$. (Restricting $q/a \in (0, 1]$ ensures that $\theta^* \in (\frac{1}{2}, 1]$ in equilibrium.) Firms, expecting that consumers expand their attention, set equilibrium prices $p_{AB} = 2\sqrt{2}\theta^*$. As derived previously, if both firms make the same attribute prominent, then equilibrium prices are $p_k = 2\mu$. Both firms earn more profits by announcing different attributes whenever $p^*_{AB} = 2\sqrt{2}\theta^*\mu > 2\mu$. This occurs if and only if $\theta^* > \sqrt{2}/2$, or equivalently, when $q/a > \sqrt{2} - 1$. When the marginal opportunity cost of attention is small (small a) or there is a significant importance to the category (large q), firms announce the different attributes in equilibrium. Because of the attention expansion, consumers appreciate their chosen product more than when they consider only one attribute and are, therefore, willing to pay more. This extension shows the necessity of constrained attention for the existence of the dilution effect as discussed in the previous section.

4. Attribute Prominence with Quality Advantages

In this section, we extend the above setting and consider firms with a quality advantage in one attribute. Our objective is to see when and how quality advantages in an attribute interact with the dilution effect. We first consider exogenous quality advantages in which firms have an inherent advantage in an attribute. We focus on the case of symmetric advantage, in which each firm has a unique advantage in one attribute. We also contrast this with the case in which one firm has an advantage in both attributes. In Section 5, we allow quality advantages to be endogenous.

Define $\Delta_k \equiv q_{1k} - q_{2k}$ to be firm 1's quality advantage in attribute k. Without loss of generality, assume $q_{1A} = q_{2B} = q^H$, and $q_{1B} = q_{2A} = q^L$, with $q^H > q^L$ so that firm 1 has the quality advantage on attribute A and firm 2 has the quality advantage on attribute B. Lemma 2 shows that if only one attribute is prominent, then firms have opposing preferences for which one.

Lemma 2. *Let $\Delta = \Delta_A = -\Delta_B = q^H - q^L > 0$. If both firms make attribute $A(B)$ prominent, then firm 1(2)'s corresponding equilibrium price, market share, and profit are higher than firm 2(1).*

When firms announce the same prominent attribute, consumers evaluate products only on that attribute. Therefore, one firm appears to have an absolute quality advantage over the other. Naturally, the better quality firm enjoys a larger market share and a higher price. Lemma 2 does not say, however, whether such a quality advantage is sufficient to overturn the mutual benefit of avoiding the dilution effect. Suppose, for example, firm 1 announces attribute A. Is it better for firm 2 to announce attribute B to neutralize the quality advantage, or should firm 2 announce attribute A to avoid the dilution effect? Proposition 2 shows that the answer depends on the relative strength of the quality advantage.

Proposition 2. *There exists a threshold $\bar{\Delta} > 0$ such that if $\Delta < \bar{\Delta}$, then both firms make the same attribute prominent in equilibrium; otherwise they make different attributes prominent.*

The main intuition of Proposition 2 ($\Delta > 0$) extends that of Proposition 1 ($\Delta = 0$). Regardless of the size of Δ, announcing different attributes dilutes consumer attention into two attributes. If $\Delta < \bar{\Delta}$ is small, the quality differentiation is not large enough to offset advantages in quality. That is, even though firm 2 with, say, a quality advantage in attribute B, it may prefer to join firm 1 in emphasizing attribute A to avoid the dilution effect.[18] Only when $\Delta > \bar{\Delta}$ is large, does firm 2 prefer to accentuate its quality by announcing attribute B.

One can also consider the case of $q_{1A} = q_{1B} = q^H$, and $q_{2A} = q_{2B} = q^L$, so that the quality advantage for firm 1 is the same for attributes A and B: $\Delta_A = \Delta_B > 0$. Firm 2 has no quality advantage regardless of the announcement strategy. For the case of an asymmetric quality advantage, it can be shown that firm 2 prefers the outcome with the most variation in the match value. (See Lemma SA1 in the online appendix.) By contrast, firm 1's profit is U-shaped in μ. Firm 1 prefers less variance whenever μ is less than some threshold $\bar{\mu}_\Delta$ and more variance when μ exceeds this threshold. From firm 1's perspective, a small μ means little horizontal differentiation. Because firm 1 owns all of the vertical differentiation, a larger μ simply gives firm 2 more market share. However, when μ is large, the vertical differentiation is relatively less important and both firms gain from more match value variance.

The differential impact of μ on firms' profits, when $\mu < \bar{\mu}_\Delta$, has an important implication for the equilibrium in prominent attributes. Firm 1 wants consumers to consider products on both attributes because it has the advantage on both. For a small μ, firm 1 gains little from avoiding the dilution effect. By contrast, firm 2 has no competitive advantage other than extreme match values and therefore wants the consumer to consider only one attribute to avoid the dilution effect. This divergence leads to what we call a "cat-and-mouse" equilibrium. (See Proposition SA3 in the online appendix for a formal argument.) Firm 1 (i.e., the mouse) plays a mixed strategy, choosing each

attribute with equal probability to avoid firm 2's (i.e., the cat) attempt to choose the same attribute. Firm 2 plays an identical mixed strategy, however, hoping to catch firm 1's attribute choice. Only when μ is large enough, do both firms prefer avoiding the dilution effect and announce the same attribute in equilibrium.

5. Prominent Attribute Strategies Under Endogenous Quality

In the previous section, we assumed quality differences were exogenously specified. However, as seen in Section 1, firms may target certain attributes for quality improvements. We consider two different timings. The first is the timing in which the investment decision is made after the attribute decision. This setting attempts to capture the situation in which positioning an attribute as prominent is harder to establish and modify relative to an incremental quality improvement. Second, we reverse the timing so that quality investment precedes attribute choice. This case captures situations in which attribute prominence can be affected more readily than quality investment. Our focus, in both situations, is to determine whether limited attention, and the implied dilution effect, can deter a firm's investment.

5.1. Quality Investment After Prominence Decision

In this section, we study the decision of prominent attributes when firms can subsequently invest in quality. While the dilution effect served to intensify price competition, as we show in the case of endogenous quality, the dilution effect may help firms avoid intense competition on quality.

We consider a multi-stage game to accommodate the prominent attribute-quality decisions made by firms. In the first stage, firms simultaneously choose their prominent attributes. In the second stage, after both firms' choices of prominent attributes are known, firms choose whether to invest in the quality of their prominent attribute. Firms then set product prices in stage three. Finally, consumers form their preferences and make their purchase decisions as in Section 2. This multi-stage timing reflects settings in which firms make quality decisions after attributes have been well established as prominent (e.g., the Volvo case cited in Section 1).

Consumer decisions are the same as the benchmark model given in Section 2. Therefore, we only discuss the quality investment decision stage. Each firm is endowed with the same quality level, q^L, in all attributes, but they can spend $c > 0$ in stage 2 to improve product quality in one attribute to q^H. For simplicity, we assume the binary quality outcomes (H or L), but our results are quantitatively unchanged with continuous quality. Finally, we assume that it is too costly for firms to invest in both attributes so that each firm can only invest in one. This allows us to focus on the connection between the choice of the prominent attribute and the decision on quality investment.

We first derive the equilibrium quality decisions for each prominent attribute outcome and then the equilibrium decisions on prominent attributes. A key aspect of this model is that, regardless of the prominent attribute decision in stage one, a firm enjoys a quality advantage only if it invests in quality and the rival firm does not. If both firms invest in quality, then the advantage is competed away in prices. Hence, firms are always worse off when they both invest relative to when they both do not invest. Nevertheless, if investment costs are not too high, then a prisoner's dilemma ensues and investing in quality is a dominant strategy. We are particularly interested in situations in which firms can avoid a prisoner's dilemma by their choice of prominent attributes in stage one. Lemma 3 raises this possibility that firms choose different attributes.

Lemma 3. (a) *If firms make the same attribute prominent, then there exists $\bar{c} > 0$ such that both firms invest in quality when $c < \bar{c}$.*

(b) *If firms make the different attribute prominent, then there exists $\underline{c} > 0$ such that both firms do not invest in quality when $c > \underline{c}$.*

If firms make the same attribute prominent, then according to Lemma 3(a), both firms' dominant strategy is to invest in quality as long as c is not too large. Under this scenario firms overinvest in quality because of competitive pressure. If firms choose different attributes, so that consumers evaluate products on both attributes, then as long as c is sufficiently large, firms can avoid the prisoner's dilemma. Overall, Lemma 3 implies that firms may choose to emphasize different attributes as a commitment to avoid competition on quality, but only if $\underline{c} < \bar{c}$.

Lemma 4. *For any $\mu > 0$, there exists a threshold $\hat{\Delta}(\mu) > 0$ such that if $\Delta < \hat{\Delta}(\mu)$, then $\underline{c} < \bar{c}$.*

Lemma 4 establishes that when Δ is not too high, there exists a well defined range of investment costs $c \in (\underline{c}, \bar{c})$ such that, if firms make the same attribute prominent, then they will invest in quality; if firms make different attributes prominent, they will not invest in quality. For both firms to make different attributes prominent in equilibrium it must be mutually beneficial to avoid the prisoner's dilemma. Recall from Proposition 2 that the dilution effect is stronger than the quality advantage effect when Δ is not too large. As discussed in Section 3, this was due to intensified price competition from a lower variance in $\mu_{AB}\varepsilon_{ij}$. Thus, firms would prefer to be in the prisoner's dilemma with quality competition rather than incurring a severe dilution effect if $c < (1 - \sqrt{2}/2)\mu$.

Proposition 3. *When $\Delta < \hat{\Delta}(\mu)$, firms make different attributes prominent for any $c \in (\max\{\underline{c}, (1-\sqrt{2}/2)\mu\}, \bar{c})$.*

We are assured that the conditions for Proposition 3 occur in our model by Lemmas 3 and 4. The proposition states that, under these conditions, firms announce different attributes in equilibrium. They do this despite, and because of, the adverse consequences of the dilution effect. While the dilution effect has a downward impact on profits due to more intense price competition, the dilution effect also lowers the incentive to invest in quality when Δ is not too large. This extension shows that, by contrast to Proposition 2, the dilution effect can discourage firms from competing on quality. That is, firms can dilute consumer attention by making both attributes prominent so that a unilateral investment in quality in one attribute does not bring a sufficient advantage to induce a prisoner's dilemma.

5.2. Quality Investment Before Prominence Decision

In this section, we study a situation in which the prominence decision can be interpreted as more flexible than an investment in quality. For instance, an innovation in an attribute may require a long-term investment after which the firm can choose whether to make it a prominent attribute, or firms may try to excel on one attribute so they can have some unique aspects to communicate (Shugan 1987). The goal is to understand whether the dilution effect in the second stage can undermine firms' incentive to invest in the first stage. To study this, we compare two different scenarios. The first is a benchmark case in which consumers are restricted to an evaluation on exactly one attribute. This is the simplest way to study the model when the dilution effect cannot affect the investment decision. We compare the benchmark case with a second scenario, i.e., the full model with the possibility that firms announce different attributes, so that the dilution effect is a strategic possibility. Through this comparison, one can establish that the dilution effect alone can deter investments in quality, when that investment would otherwise occur. (See the online appendix for a detailed analysis.)

Under this timing, firms can coordinate on the same attribute after choosing not to invest. When a firm considers investing in an attribute in the first stage, it knows there is a credible threat that the other firm will not coordinate on attribute announcements in the second stage: When Δ is large, the firm that does not invest in the first stage can threaten to announce a different prominent attribute in the second stage. This threat is credible and, therefore, facilitates the coordination of firms to not invest in quality in the beginning. In summary, regardless of the timing of the investment choice relative to the attribute prominence choice, we have shown that the dilution effect can have a deterrent effect on quality investment. However, the outcome and the mechanism in the two settings are different.

6. Conclusion

The premise of this research is that firms face limitations when communicating to consumers, i.e., limited attention and narrow bandwidth. These limitations imply that a firm cannot provide a full description of each of its product's attributes and that consumers do not necessarily devote all of their attention to all product attributes before purchase. Consequently, a consumer's preference over available products depends on which attributes marketers choose to highlight or make prominent. In competitive scenarios, one firm's decision on a prominent attribute affects how a consumer evaluates other firms' products. Our model examined the corresponding strategic interactions between firms deciding which attribute to make prominent. The model points to several results.

First, symmetric firms, which are horizontally differentiated, choose the same attribute to make prominent. With limited consumer attention, firms jointly prefer consumers to devote their attention to a few attributes. When consumers evaluate on multiple attributes they perceive less horizontal differentiation because they split their attention across the attributes: We call this the dilution effect. This result was derived from a model of two firms selling products with two attributes. When each firm has a unique quality advantage in exactly one attribute, our model finds that firms may still emphasize the same single attribute. Only if the quality advantages are sufficiently large will firms emphasize different attributes in equilibrium.

Next, we considered the case in which one firm dominates in both attributes. In this case, the two firms' preferences over prominent strategies can diverge. The dominant firm may prefer that consumers evaluate products on both attributes so as to accentuate all of its quality advantages. The other firm, by contrast, prefers that consumers consider only one attribute so as not to be subject to the dilution effect. This leads to firms playing mixed strategies, with the dominant firm trying to make its choice of prominent attribute unpredictable for the other firm.

Finally, we considered the case in which firms could strategically invest in the quality of their prominent attribute. We showed that the dilution effect can be used as a threat to investments in quality. When firms are permitted to make incremental quality improvements after making the same attribute prominent, there is a prisoner's dilemma in which firms invest in quality but compete away any additional profits. To avoid that prisoner's dilemma, firms make different attributes prominent to ensure that the dilution effect erodes a unilateral benefit from investing in quality. When firms must make investment decisions before committing to a prominent attribute, the threat of the dilution effect by the non-investing firm in the second

stage keeps the unilateral benefit of investing sufficiently low to prevent investment in the first stage.

Our research points to a few areas for future inquiry. Perhaps the most obvious avenue for future research is examining the question of how consumers optimally allocate their attention when it is limited. The notion that consumers pay differential attention across attributes when making a choice has only recently received attention in the economics literature (Kőszegi and Szeidl 2013, Bordolo et al. 2013). Still, to our knowledge, no research has focused on the manner in which consumers allocate their attention. Examining the consumers' attention allocation problem could have important implications for marketers when communicating product information.

In reality consumers may be unable to evaluate the product's quality before purchase, especially when their attention is limited. In such situations, a firm's attribute choice not only discloses the importance of the attribute but may also "signal" the quality of the product in this attribute. Incorporating the signaling role of choosing a prominent attribute may be a useful direction for future research. In addition, it would be interesting to consider the interaction between product line decisions (Joshi et al. 2016) and prominent attribute strategies.

The literature on the economics of search, while large, typically focuses on product evaluation at a holistic level and has only recently begun to examine the case in which consumers search at the attribute-level (e.g., Bar-Isaac et al. 2012, Branco et al. 2012, Ke et al. 2016, Liu and Dukes 2016). None of this work, however, has studied the case in which attributes differ in terms of the differential attention that consumers pay to certain attributes. To our knowledge, there has been no attempt to develop a fully strategic model that studies firms' strategic decisions on attribute prominence and consumers' optimal decisions in information search at the attribute-level. Developing an alternative modeling of consumers with more microfoundations of consumer learning and attention allocation would be a fruitful line of inquiry.

In our competitive model, we assumed that firms moved simultaneously in their announcements of attributes. Yet consumers encounter some firms before others; some firms have a timing advantage in moving more quickly than their rivals. It is reasonable to anticipate that sequential exposure might have differential context biases on consumer's attention. For instance, if recency effects are significant, then moving last would lend that marketer an advantage in directing consumer attention where it wants. By contrast, primacy effects would do the opposite. The presence of either form of bias would have implications for how firms strategically time their announcement of a prominent attribute.

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Appendix

This appendix provides the proofs of all results in the main text.

Before proving Lemma 1, we formalize the approximation used in all of the results. The approximation can be interpreted as the choice framework in Section 2 except that each firm carries $n \geq 1$ products, with identical quality within each firm. Consider a sequence of i.i.d. random variables $\{\nu_k \varepsilon_{ijk}\}_{i=1}^{n}$, where $\varepsilon_{ijk} \sim N(0,1)$ and $\nu_k > 0$. Define $M_{jk} \equiv \max_{1 \leq i \leq n}\{\nu_k \varepsilon_{ijk}\}$ as the maximum random-match value obtained when evaluating all n products from firm j on attribute(s) $k \in \{A, B, AB\}$. (Note that $i^*(j,k) = \arg\max_i\{\nu_k \varepsilon_{ijk}\}$ is the consumer's most preferred of the n products offered by firm j.) Fix $j = 1, 2$ and, with a slight abuse of notation, $k = A, B, AB$. Consider the sequence $\{\nu_k \varepsilon_{ijk}\}_{i=1}^{n}$, which is an i.i.d. sample of size n from $N(0, \nu_k^2)$, the normal distribution with zero mean and variance ν_k^2. de Haan and Ferreira (2006) show that the Fisher–Tippet–Gnedenko Theorem implies that the distribution of M_{jk} approximates that of a type-I, extreme-value random variable with a cdf

$$\Pr[M_{jk} < x] \cong e^{-e^{-n\Phi'(a_n)x/\nu_k}},$$

where $a_n = \Phi^{-1}(1 - 1/n)$. This approximation reflects the convergence as $n \to \infty$ of $\nu_k \max\{\varepsilon_{ijk}\} \to_D \mu_k \sigma_{jk}$, where σ_{jk} is a standard type-I extreme value random variable and $\mu_k = \nu_k(1/(n\Phi'(a_n)))$. Thus, for any k, the consumer's choice of a firm approximates a logit choice framework.

Proof of Lemma 1. Using the above approximation, suppose a consumer evaluates products on one attribute, $k = A$ or B, only. Then her choice of firm depends only on the best product from each firm

$$u_{jk} = \max\{u_{ijk}\} = V + q_{jk} - p_j + \max\{\nu_k \varepsilon_{ijk}\}.$$

In this case, the consumer chooses firm 1 if and only if $u_{1k} > u_{2k}$, or equivalently

$$M_{1k} > \frac{(q_{2k} - q_{1k}) - (p_2 - p_1)}{\mu_k} + M_{2k}, \quad k = A, B,$$
$$\mu_k = v_k \left[\frac{a_n}{n\Phi'(a_n)} \right],$$

which occurs with probability $s_{1k} = 1 - s_{2k}$, as shown in Anderson et al. (1992), and is expressed in the first part of Lemma 1. Suppose a consumer evaluates products on both attributes so that $v_{AB}\varepsilon_{jAB} \approx_D \mu_{AB}\sigma_{jAB}$, where $\mu_{AB} = \frac{1}{2}\sqrt{\mu_A^2 + \mu_B^2}$ and σ_{jAB} is a random variable with standard, type-1 extreme value distribution. For $\mu_A = \mu_B = \mu$, $\mu_{AB} = (\sqrt{2}/2)\mu$. The consumer chooses firm 1 if and only if $u_{1AB} > u_{2AB}$, which is equivalent to

$$M_{1AB} > \frac{(q_{2A} - q_{1A}) + (q_{2B} - q_{1B}) - (p_2 - p_1)}{2\mu/\sqrt{2}} + M_{2AB},$$

which occurs with probability $s_{1AB} = 1 - s_{2AB}$ and is expressed in the second part of Lemma 1. □

Proof of Proposition 1. Based on Lemma 1, we know that firm j's profit when consumers evaluate attribute(s) k ($k = A, B, AB$) is equal to $\pi_{jk} = p_j s_{jk}$ where s_{jk} is given in Lemma 1. The first order condition gives us $\partial\pi_{jk}/\partial p_j = s_{jk} + p_j(\partial s_{jk}/\partial p_j) = s_{jk} - (1/\mu_k)s_{jk}s_{-jk}p_j = 0$, where $-j \neq j$. Therefore we know $p_j = \mu_k(1/s_{-jk})$, and the profit is equal to $\pi_{jk} = \mu_k(s_{jk}/s_{-jk})$. The condition $\Delta = 0$ directly implies that in equilibrium $s_{jk} = s_{-jk} = \frac{1}{2}$. Therefore $\pi_{jk} = \pi_{-jk} = \mu_k$. Since $\mu_A = \mu_B > \mu_{AB}$, firms will prefer to announce the same attribute. □

Proof of Lemma 2. The consumer's utility from firm j when evaluating only attribute k is $u_{jk} = V - p_j + q_{jk} + \mu_k \max\{\varepsilon_{ijk}\}$, where $\max\{\varepsilon_{ijk}\}$ is distributed as a type I extreme value distribution by Lemma 1. Anderson et al. (1992) established that there exists a unique price equilibrium in the same setting. Moreover, Anderson et al. (1992) show that as the quality difference Δ increases, the equilibrium price of the high quality firm increases as well. Hence, $\Delta_k > 0$ leads to $p_1 > p_2$. From firms' first order conditions, $p_j = \mu/s_{-jk}$, we further deduce that $s_{1k} > s_{2k}$. Correspondingly, the profit for firm 1 is larger than for firm 2. □

Proof of Proposition 2. When firms announce different attributes, the consumer's utility when buying from firm j is $u_{jAB} = (V - p_j) + \frac{1}{2}q_{jA} + \frac{1}{2}q_{jB} + \mu_{AB}\varepsilon_{jAB}$. In the symmetric equilibrium both firms have equal market share, prices, $p_1 = p_2 = 2\mu_{AB}$, and profit, $\pi_{1AB} = \pi_{2AB} = \mu_{AB}$. Suppose, without loss of generality, firm 1 makes attribute A prominent. Let π_{1A} and π_{2A} be firms' profits when both make attribute A the prominent attribute. From Lemma 2 we know that $\pi_{1A} > \pi_{2A}$ and that $\partial\pi_{2A}/\partial\Delta < 0$ for $\Delta > 0$. We also know that $\lim_{\Delta\to 0}\pi_{2A} \to \mu_A > \mu_{AB}$ (from Proposition 1). Furthermore, $\lim_{\Delta\to\infty} s_{2k} = 0$ (from Lemma 1), so that $\lim_{\Delta\to\infty}\pi_{2A} \to 0$. Because π_{2A} is strictly monotonically decreasing in Δ, there exists a $\bar{\Delta} > 0$ such that $\pi_{2A} > \pi_{2AB}$ whenever $\Delta < \bar{\Delta}$. Under this condition, it is beneficial for firm 2 to make attribute A prominent as well, rather than attribute B. Yet when $\Delta > \bar{\Delta}$, we have $\pi_{2A} < \pi_{2AB}$ so that firm 2 will choose to make attribute B prominent. Similarly, $\pi_{1AB} > \pi_{1B}$, which means firm 1 prefers to make attribute A prominent when firm 2 makes attribute B prominent. Thus, firms make different attributes prominent in equilibrium whenever $\Delta > \bar{\Delta}$. □

Figure A.1. Payoff Matrix When Firms Make Attribute k Prominent

	Firm 2	
Invest on quality	Y	N
Firm 1		
Y	$\pi_{1k}^{HH} - c, \pi_{2k}^{HH} - c$	$\pi_{1k}^{HL} - c, \pi_{2k}^{HL}$
N	$\pi_{1k}^{LH}, \pi_{2k}^{LH} - c$	$\pi_{1k}^{LL}, \pi_{2k}^{LL}$

Proof of Lemma 3. For Lemma 3(a), when both firms make attribute k prominent, each firm's payoff when deciding on the investment is given by the 2×2 matrix of Figure A.1.

In this payoff matrix, π_{1k}^{HL} represents firm 1's profit when the prominent attribute is k and firm 1 invests in quality (so the quality is q^H) and firm 2 does not invest (so the quality remains at q^L).

We can see that when both firms improve the quality, they have the same quality q^H and therefore share the market equally with payoff $\pi_{1k}^{HH} = \pi_{2k}^{HH} = \mu$. Similarly, we know that $\pi_{1k}^{LL} = \pi_{2k}^{LL} = \mu$. We can also see $\pi_{2k}^{LH} = \pi_{1k}^{HL} = \bar{\pi}_k > \mu > \pi_{1k}^{LH} = \pi_{2k}^{HL} = \underline{\pi}_k$ based on Lemma 2. Define $\bar{c} = \min\{|\bar{\pi}_k - \mu|, |\underline{\pi}_k - \mu|\} > 0$. Then when $c < \bar{c}$, $\mu - c > \underline{\pi}_k$, and $\bar{\pi}_k - c > \mu$. Firm 1's dominant strategy is to invest on quality regardless of firm 2's strategy, and vice versa for firm 2. Therefore, the equilibrium has both firms investing on quality.

The proof for Lemma 3(b) is quite similar to Lemma 3(a). When both firms make different attributes prominent, each firm's payoff when deciding on the investment is given by the 2×2 matrix in Figure A.2.

We know that the payoff $\pi_{1AB}^{HH} = \pi_{2k}^{HH} = (\sqrt{2}/2)\mu$. Similarly, we know that $\pi_{1AB}^{LL} = \pi_{2AB}^{LL} = (\sqrt{2}/2\mu)$. We can also see $\pi_{2AB}^{LH} = \pi_{1AB}^{HL} = \bar{\pi}_{AB} > (\sqrt{2}/2)\mu > \pi_{1k}^{LH} = \pi_{2k}^{HL} = \underline{\pi}_{AB}$ based on Lemma 2. Let's define $\underline{c} = \max\{|\bar{\pi}_{AB} - (\sqrt{2}/2)\mu|, |\underline{\pi}_{AB} - (\sqrt{2}/2)\mu|\} > 0$. We can see that when $c > \underline{c}$ firm 1's dominant strategy is to not invest in quality, and vice versa for firm 2. The equilibrium has neither firm investing in quality. □

Proof of Lemma 4. We prove this lemma by first showing that $\bar{c} = \min\{|\bar{\pi}_k - \mu|, |\underline{\pi}_k - \mu|\} = \mu - \underline{\pi}_k$, and $\underline{c} = \max\{|\bar{\pi}_{AB} - (\sqrt{2}/2)\mu|, |\underline{\pi}_{AB} - (\sqrt{2}/2)\mu|\} = (\bar{\pi}_{AB} - (\sqrt{2}/2)\mu)$. Intuitively, it means the marginal increase in profit for the firm that improves the quality is larger than the corresponding decrease in profit for the low quality firm. Then we show there always exist a $\hat{\Delta}(\mu) > 0$ such that when $\Delta < \hat{\Delta}(\mu)$ we have $\underline{c} < \bar{c}$.

Figure A.2. Payoff Matrix When Firms Make Different Attributes Prominent

	Firm 2	
Invest on quality	Y	N
Firm 1		
Y	$\pi_{1AB}^{HH} - c, \pi_{2AB}^{HH} - c$	$\pi_{1AB}^{HL} - c, \pi_{2AB}^{HL}$
N	$\pi_{1AB}^{LH}, \pi_{2AB}^{LH} - c$	$\pi_{1AB}^{LL}, \pi_{2AB}^{LL}$

By assumption, when both firms do not invest, they have the same quality q^L. So $\Delta_k = 0, \forall\, k = A, B$. Now assume firm 1 invests to increase its product quality to q^H in attribute k so that $\Delta \equiv \Delta_k > 0$. We know that $\pi_{1k}^{HL} = \bar{\pi}_k > \mu > \pi_{2k}^{HL} = \underline{\pi}_k$. What we want to show is $\pi_{1k}^{HL} - \mu > \mu - \pi_{2k}^{HL}$, or equivalently $d\pi_1/d\Delta + d\pi_2/d\Delta > 0$. To show this, we again refer to the firm's first order condition that

$$F_1(p_1, p_2; \Delta) \equiv \mu - p_1 s_2 = 0, \tag{A.1}$$

$$F_2(p_2, p_1; \Delta) \equiv \mu - p_2 s_1 = 0. \tag{A.2}$$

We know from (A.1) and (A.2) that

$$\frac{\partial F_1}{\partial p_1} = -1, \quad \frac{\partial F_1}{\partial p_2} = s_1, \quad \text{and} \quad \frac{\partial F_1}{\partial \Delta} = -p_1 \frac{\partial s_2}{\partial \Delta} = p_1 \frac{1}{\mu} s_1 s_2 = s_1;$$

$$\frac{\partial F_2}{\partial p_1} = s_2, \quad \frac{\partial F_2}{\partial p_2} = -1, \quad \text{and} \quad \frac{\partial F_2}{\partial \Delta} = -s_2.$$

Taking the total derivatives and rearranging we have

$$\frac{dp_1}{d\Delta} = \frac{+\frac{\partial F_2}{\partial p_2}\frac{\partial F_1}{\partial \Delta} + \frac{\partial F_1}{\partial p_2}\frac{\partial F_2}{\partial \Delta}}{\frac{\partial F_1}{\partial p_1}\frac{\partial F_2}{\partial p_2} + \frac{\partial F_1}{\partial p_2}\frac{\partial F_2}{\partial p_1}} = \frac{s_1^2}{1 - s_1 s_2}; \quad \text{and}$$

$$\frac{dp_2}{d\Delta} = \frac{+\frac{\partial F_2}{\partial p_1}\frac{\partial F_1}{\partial \Delta} - \frac{\partial F_1}{\partial p_1}\frac{\partial F_2}{\partial \Delta}}{\frac{\partial F_1}{\partial p_1}\frac{\partial F_2}{\partial p_2} - \frac{\partial F_1}{\partial p_2}\frac{\partial F_2}{\partial p_1}} = \frac{-s_2^2}{1 - s_1 s_2}.$$

We know that

$$\frac{d\pi_1}{d\Delta} = \frac{\partial \pi_1}{\partial p_2}\frac{dp_2}{d\Delta} + \frac{\partial \pi_1}{\partial \Delta} = p_1 \frac{\partial s_1}{\partial p_2}\frac{dp_2}{d\Delta} + p_1 \frac{\partial s_1}{\partial \Delta}$$

$$= p_1 \frac{1}{\mu} s_1 s_2 \left(\frac{-s_2^2}{1 - s_1 s_2} + 1 \right) = p_1 \frac{1}{\mu} s_1 s_2 \frac{s_1}{1 - s_1 s_2} = \frac{s_1^2}{1 - s_1 s_2} > 0;$$

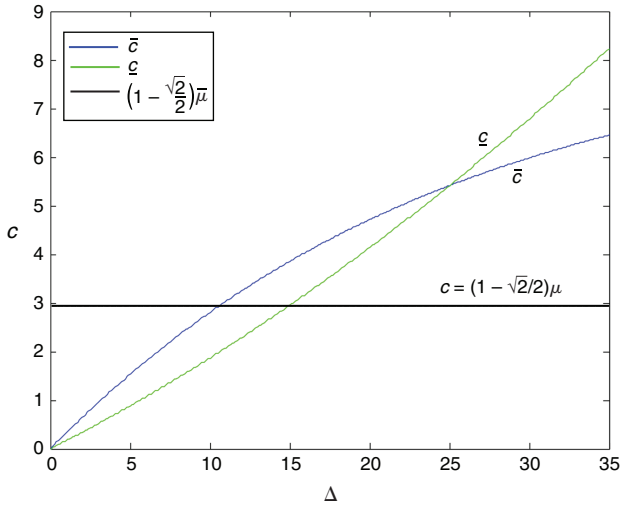
$$\frac{d\pi_2}{d\Delta} = \frac{\partial \pi_2}{\partial p_1}\frac{dp_1}{d\Delta} + \frac{\partial \pi_2}{\partial \Delta} = p_2 \frac{\partial s_2}{\partial p_1}\frac{dp_1}{d\Delta} + p_2 \frac{\partial s_2}{\partial \Delta}$$

$$= p_2 \frac{1}{\mu} s_1 s_2 \left(\frac{s_1^2}{1 - s_1 s_2} - 1 \right) = \frac{-s_2^2}{1 - s_1 s_2} < 0.$$

Since $p_1 > p_2$ when $\Delta > 0$, we can see that $d\pi_1/d\Delta + d\pi_2/d\Delta > 0$. Therefore we know that $\pi_{1k}^{HL} - \mu > \mu - \pi_{2k}^{HL}$, which gives us $\bar{c} = \mu - \underline{\pi}_k$. The proof for $\underline{c} = (\bar{\pi}_{AB} - (\sqrt{2}/2)\mu)$ is very similar and therefore omitted.

Next we show that there always exists a $\hat{\Delta}(\mu) > 0$ for any given μ such that when $\Delta < \hat{\Delta}(\mu)$, we have $\underline{c} < \bar{c}$. $\underline{c} < \bar{c} \Leftrightarrow \bar{\pi}_{AB} - (\sqrt{2}/2)\mu < \mu - \underline{\pi}_k \Leftrightarrow \bar{\pi}_{AB} + \underline{\pi}_k < \mu + (\sqrt{2}/2)\mu$. We can see when $\Delta = 0$, $\bar{\pi}_{AB} + \underline{\pi}_k = \mu + (\sqrt{2}/2)\mu$. Next we check the sign of $d(\bar{\pi}_{AB} + \underline{\pi}_k)/d\Delta$. We know that $d\underline{\pi}_k/d\Delta = -s_{2k}^2/(1 - s_{1k}s_{2k})$, and $d\bar{\pi}_{AB}/d\Delta = s_{1AB}^2/(1 - s_{1AB}s_{2AB})$. However, when both attributes are prominent, the quality advantage is diluted and the variance becomes small. To see this, consider the following example: If firm 1 invests in quality in attribute A, and firm 2 does not match the investment, the consumer's utility of buying from firm 1 is $u_{1AB} = V - p_1 + \frac{1}{2}q^H + \frac{1}{2}q^L + (\sqrt{2}/2)\mu \max\{\varepsilon_{i1AB}\}$, and from firm 2 is $u_{2AB} = V - p_1 + q^L + (\sqrt{2}/2)\mu \max\{\varepsilon_{i2AB}\}$. The overall vertical difference due to the quality becomes $\frac{1}{2}\Delta$, which is lower than the difference Δ when firms make the same attribute prominent. Because of that, $d(\bar{\pi}_{AB} + d\underline{\pi}_k)/d\Delta = d\underline{\pi}_k/d\Delta + \frac{1}{2}d\bar{\pi}_{AB}/d\Delta = -s_{2k}^2/(1 - s_{1k}s_{2k}) + \frac{1}{2}(s_{1AB}^2/(1 - s_{1AB}s_{2AB}))$. Therefore, $d(\bar{\pi}_{AB} + \underline{\pi}_k)/d\Delta|_{\Delta\to 0} = -s_{2k}^2/(1 - s_{1k}s_{2k}) + \frac{1}{2}(s_{1AB}^2/(1 - s_{1AB}s_{2AB}))|_{\Delta\to 0} = -\frac{1}{6}$ (since s_{2k} and s_{1AB} are equal to $\frac{1}{2}$ when $\Delta \to 0$). Hence, we show that $\bar{\pi}_{AB} + \underline{\pi}_k < \mu + (\sqrt{2}/2)\mu$ when $\Delta \to 0$. Because of the continuity of profit functions, there must exist a threshold $\hat{\Delta}(\mu) > 0$ such that when $\Delta < \hat{\Delta}(\mu)$, we have $\underline{c} < \bar{c}$. □

Figure A.3. (Color online) Illustration of $\underline{c}$, $\bar{c}$, and $(1 - \sqrt{2}/2)\mu$ when $\mu = 10$ and $\Delta \in [0, 35]$



Proof of Proposition 3. When $\Delta < \hat{\Delta}(\mu)$, from Lemma 4 we know that $\underline{c} < \bar{c}$, which leads to the firms' payoff $(\sqrt{2}/2)\mu$ if making both attributes prominent, and $\mu - c$ if making a single attribute k prominent. Hence, when $c > \mu - (\sqrt{2}/2)\mu$ we have $(\sqrt{2}/2)\mu > \mu - c$, which gives us the required conditions for firms to make different attributes prominent in equilibrium. Figure A.3 illustrates $\underline{c}$, $\bar{c}$, and $(1 - \sqrt{2}/2)\mu$ by simulation. □

Endnotes

[1] This is based on surveys of business managers and in-depth interviews with marketing executives. (See the detailed description of interviews and survey results in the online appendix.)

[2] For instance, firms are often limited to a 30-second commercial, a single page ad in a magazine or a side-banner on a webpage.

[3] In this way, our paper connects to Anderson and Renault (2009), which studies a model of comparative advertising in which a firm can reveal to consumers horizontal match information about competitive products. Advertising in our model can be interpreted as revealing partial (single attribute) match information about both products.

[4] Independence is not necessary for our results and is made for analytical convenience. Section 3.2 provides a discussion of the impact of correlation in attribute match values; see the online appendix for additional analysis.

[5] Consumer psychology literature connects the amount of attention paid to an attribute to its importance in decision making. For example, Fishbein and Aizen (1975) argue that "attributes that are important are typically evaluated more positively or negatively (i.e., are more polarized) than attributes that are unimportant" (p. 228) as cited in MacKenzie (1986). Thus, the more important attribute $k \in \{A, B, AB\}$ is considered, the greater the polarity, or variance, of the term $\theta_k \nu_k$.

[6] In this model we capture the effect of firms' announcements on consumer preferences at the category level. This feature has an alternative interpretation of persuasive advertising in which a firm's

announcement affects consumer utility, but for all products in a category. On the other hand, one might envision a traditional product-specific persuasion element for this model. However, incorporating this into the model would not affect consumers' decisions in equilibrium since the competitive effect of such persuasion will cancel out in our symmetric setting.

[7] See the online appendix for details.

[8] This approximation borrows from the Extreme Value Theory and is interpreted as follows: Suppose each firm sells $n > 1$ products, each defined by the attribute-specific match value ε_{ijk}, $i = 1, \ldots, n$. The consumer's choice among firms equates to a choice across $u_{jk} = V - p_j + \theta_A q_{jA} + \theta_B q_{jB} + \nu_k \max_i\{\varepsilon_{ijk}\}$, where attribute(s) $k \in \{A, B, AB\}$ is evaluated. As n becomes large, $\nu_k \max\{\varepsilon_{ijk}\} \to_D \mu_k \sigma_{jk}$, where $\mu_k \sigma_{jk}$ is distributed as a type-I extreme value. See the online appendix for more details of this approximation.

[9] In the current model we assume the market is fully covered by two firms and that there are no outside options. Our results are quantitatively unchanged if consumers have an outside option. See the online appendix for details.

[10] Because of our interest in competitive interactions in the prominence decision, we do not present the case of a monopoly. The monopolist's problem of attribute prominence can be mapped to the modeling framework of Johnson and Myatt (2006).

[11] We discuss the asymmetric attribute case in Section 3.2.

[12] The conditions of Proposition 1 do not rule out multiple equilibria because firms announcing attributes A and B are two distinct equilibria. However, if we depart from this knife-edge symmetric situation, so that $\mu_A > \mu_B$ (or $\mu_A < \mu_B$), then both firms choosing attribute A (or, respectively, B) survives as the only Pareto optimal equilibrium. This argument also applies to any mixed-strategy equilibria (Schelling 1960, Harsanyi and Selten 1988).

[13] Mathematically, $E[u_{1AB} - u_{2AB} \mid u_{1A} > u_{2A}] < E[u_{1A} - u_{2A} \mid u_{1A} > u_{2A}]$.

[14] For now, we stick to the case of symmetric quality ($\Delta_k = 0, k = A, B$). The case of $\Delta_k \neq 0$ is studied in Sections 4 and 5.

[15] In fact, negative correlation weakens the need for limited attention to generate the outcome of Proposition 1. To see this, consider the case of endogenous consumer attention: In the symmetric case of $\theta = \theta_A = \theta_B$, observe that $\rho < -1/2$ implies that $\mu_{AB} = \theta\mu\sqrt{2 + 2\rho}$, which is less than μ for $\theta = 1$, the case of full attention. In other words, the necessity of limited consumer attention is weaker with negative correlation. We thank an anonymous reviewer for pointing this out.

[16] We thank an anonymous reviewer for suggesting this extension.

[17] Our analysis of endogenous attention expansion is limited to the setting in which firms announce different attributes and consumers have no outside options.

[18] Although we focus on pure-strategy equilibria, there also exists a proper mixed strategy equilibrium under the conditions of Propositions 1 and 2. When firms have no quality advantage, announcing each attribute with probability 1/2 is an equilibrium. If $\Delta_A = -\Delta_B < \bar{\Delta}$, then the symmetric mixed-strategy equilibrium has firm 1 announcing attribute A with a probability greater than 1/2 and equal to firm 2 announcing attribute B. The reasoning in this latter setting maps to the classic 2×2 game of Battle of the Sexes. On the other hand, we can see that such equilibria are evolutionarily unstable since they are dominated by pure-strategy equilibrium (Schelling 1960, Harsanyi and Selten 1988).

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