A Appendix: Further Derivations and Mathematical Complements

A.1 Further Derivations

Basic signal-extraction problem (Section 2.1) We have $s = x + \varepsilon$. So $\mathbb{E}[x|s] = ms$, with $m = \frac{\mathrm{Cov}(x,s)}{\mathrm{Var}(s)} = \frac{v_x}{v_s}$. Hence, $a = ms = mx + m\varepsilon$. A little bit of algebra gives $v_\varepsilon = v_s - v_x = v_x\left(\frac{1}{m} - 1\right)$ and

$$\mathrm{Var}(m\varepsilon) = mv_\varepsilon = m(1-m)$$

so a is distributed as:

$$a = mx + \sqrt{m(1-m)}\eta_x \tag{82}$$

where η_x is another draw from the distribution of x. This implies $\mathrm{Var}(a) = m\,\mathrm{Var}(x)$, and $\mathbb{E}\left[(a-x)^2\right] = (1-m)\sigma_x^2$.

Derivation of the losses from inattention (equation 27) Let us start with a 1-dimensional action, with a utility function $u(a)$. Call a^* the optimum. But the agent does $a = a^* + \hat{a}$, where $\hat{a}$ is a deviation (perhaps coming from inattention). Then utility losses are

$$L(\hat{a}) := u(a^* + \hat{a}) - u(a).$$

Let's do a Taylor expansion,

$$L_a(\hat{a}) = u'(a^* + \hat{a}),\ L_{aa}(\hat{a}) = u''(a^* + \hat{a})$$
$$L(\hat{a}) = L(0) + L_a(0)\hat{a} + \frac{1}{2}L_{aa}(0)\hat{a}^2 + o\left(\hat{a}^2\right)$$

which implies $L(0) = L_a(0) = 0$. Hence:

$$L(\hat{a}) = \frac{1}{2}u_{aa}(0)\hat{a}^2 + o\left(\hat{a}^2\right).$$

Next, for a small x, the deviation is

$$\hat{a} = a^*(x^s) - a^*(x) = a_x(x^s - x) + o(x) = a_x(m-1)x + o(x)$$

hence, for a one-dimensional x, the loss is:

$$\begin{aligned} 2L(x) &= u_{aa}(a^*(x))\hat{a}^2 + o\left(\hat{a}^2\right) = u_{aa}(a^*(0))\hat{a}^2 + o\left(\hat{a}^2\right) \\ &= \frac{1}{2}u_{aa}a_x^2x^2(1-m)^2 + o\left(|x|^2\right). \end{aligned}$$

With an $n-$dimensional x, the math is similar, with matrices:

$$\hat{a} = a^* (x^s) - a^* (x) = a_x (x^s - x) = a_x (M - I) x + o(x)$$

with $M = diag(m_1, ..., m_n)$, I the identify matrix of dimension n. So, neglecting $o\left(\|\hat{a}\|^2\right)$ terms,

$$\begin{aligned}
2L &= \hat{a}' u_{aa}(0) \hat{a} + o\left(\|\hat{a}\|^2\right) = x' (I - M)' a_x' u_{aa}(0) a_x (I - M) x \\
&= -\sum_{i,j} (1 - m_i) x_i a_{x_i}' u_{aa}(0) a_{x_j} x_j (1 - m_j) \\
&= -\sum_{i,j} (1 - m_i) \tilde{\Lambda}_{ij} (1 - m_j) = -(\iota - m) \tilde{\Lambda} (\iota - m)' \\
\tilde{\Lambda}_{ij} &= -x_i a_{x_i}' u_{aa}(0) a_{x_j} x_j, \ \iota := (1, ..., 1).
\end{aligned}$$

We then obtain (27) by taking expectations.

Derivation of the entropy of Gaussian variables (Section 5.2.1) The entropy doesn't depend on the mean, so we normalized it to 0.

One dimension. The density is $f(x) = \frac{e^{-\frac{x^2}{2\sigma^2}}}{\sqrt{2\pi\sigma^2}}$, so

$$\begin{aligned}
H(X) &= -\mathbb{E}[\log f(X)] = -\mathbb{E}\left[-\frac{x^2}{2\sigma^2} - \frac{1}{2}\log\left(2\pi\sigma^2\right)\right] \\
&= \frac{1}{2} + \frac{1}{2}\log\left(2\pi\sigma^2\right) = \frac{1}{2}\log\sigma^2 + \frac{1}{2}\log(2\pi e).
\end{aligned}$$

Higher dimensions. The density is $f(x) = \frac{e^{-\frac{1}{2}x'V^{-1}x}}{(2\pi)^{n/2}(\det V)^{1/2}}$, where $V = \mathbb{E}[XX']$ is the variance covariance matrix. Using the notation $|V| = \det V$, and Tr for the trace, we first note

$$\begin{aligned}
\mathbb{E}\left[x'V^{-1}x\right] &= \mathbb{E}\left[\operatorname{Tr}\left(x'V^{-1}x\right)\right] = \mathbb{E}\left[\operatorname{Tr}\left(xx'V^{-1}\right)\right] \\
&= \operatorname{Tr}\mathbb{E}\left[xx'V^{-1}\right] = \operatorname{Tr}\mathbb{E}\left[VV^{-1}\right] = \operatorname{Tr} I_n = n.
\end{aligned}$$

Then, the entropy is

$$\begin{aligned}
H(X) &= -\mathbb{E}[\log f(X)] = -\mathbb{E}\left[-\frac{n}{2}\log(2\pi) - \frac{1}{2}\log|V| - \frac{1}{2}x'V^{-1}x\right] \\
&= \frac{1}{2}\log\left((2\pi)^n |V|\right) + \frac{n}{2} = \frac{1}{2}\log\left((2\pi e)^n |V|\right).
\end{aligned}$$

Mutual information of two Gaussian variables (Section 5.2.1) Suppose X, Y are jointly Gaussian, with variance-covariance matrix $V = \begin{pmatrix} \sigma_X^2 & \rho\sigma_X\sigma_Y \\ \rho\sigma_X\sigma_Y & \sigma_Y^2 \end{pmatrix}$, where $\rho = \operatorname{corr}(X, Y)$. Then, $\det V = \sigma_X^2 \sigma_Y^2 (1 - \rho^2)$, so

$$H(X, Y) = \frac{1}{2} \log(\det V) + n \log(2\pi e)$$

and using (51) gives

$$I(X, Y) = H(X) + H(Y) - H(X, Y) = -\frac{1}{2} \log\left(1 - \rho^2\right).$$

Proof of Proposition 6.1 From Definition 4.2, the optimum satisfies: $u'(c) = \lambda p^s$ for some λ. Hence, this consumption is the consumption of a rational agent facing prices p^s, and wealth $w' = p^s \cdot c$.

Proof of Proposition 6.3 Here I show only the proof in the most transparent case – see the original paper for the general case. Utility is $u(c) = U(C) + c_n$, where $C = (c_1, ..., c_{n-1})$, and the price of good n is 1 and correctly perceived. Then, demand satisfies $u'(c) = \lambda p^s$. Applying this to the last good gives $1 = \lambda$. So, demand for the other goods satisfies $U'(C) = P^s$, where $P = (p_1, \ldots, p_n)$. Differentiating w.r.t. P, $U''(C) C_P^s = M$, where $M = diag(m_1, \ldots, m_{n-1})$ is the vector of attention to prices. Now, the Slutsky matrix (for the goods $1, \ldots, n-1$) is $S^s = C_P^s = U''^{-1}(C) M$, as all the income effects are absorbed by the last good ($\frac{\partial c_i}{\partial w} = 0$ for $i < n$). As a particular case where $M = I$, the rational Slutsky matrix is $S^r = U''^{-1}(C)$. So, we have $S^s = S^r M$.

Proof of Proposition 6.5 The part $\frac{\partial \boldsymbol{c}^s}{\partial w} = \frac{\partial \boldsymbol{c}^r}{\partial w}$ follows from Proposition 6.1: at the default prices $\boldsymbol{p} = \boldsymbol{p}^s$, so $\boldsymbol{c}^s\left(\boldsymbol{p}^d, w\right) = \boldsymbol{c}^r\left(\boldsymbol{p}^d, w\right)$, which implies $\frac{\partial \boldsymbol{c}^s}{\partial w} = \frac{\partial \boldsymbol{c}^r}{\partial w}$. Then, the definition of the Slutsky matrix and Proposition 6.3 imply (65).

Proof of Proposition 6.8 In an endowment economy, equilibrium consumption is equal to the endowment, $\boldsymbol{c}(t) = \boldsymbol{\omega}(t)$. We have $\frac{u_i(\boldsymbol{c}(t))}{u_1(\boldsymbol{c}(t))} = \frac{p_i^s(t)}{p_1^s(t)}$ for $t = 0, 1$: the ratio of marginal utilities is equal to the ratio of perceived prices – both in the rational economy (where perceived prices are true prices) and in the behavioral economy (where they're not). Using $p_1^s(t) = p_1^r(t) = p_1(0)$, that implies that the perceived price needs to be the same in the behavioral and rational economy: $\left(p_i^{[s]}(t)\right)^{\text{perceived}} = p_i^{[r]}(t)$. Thus, we have $m_i dp_i^{[s]} = d\left[\left(p_i^{[s]}\right)^{\text{perceived}}\right] = dp_i^{[r]}$, i.e. $dp_i^{[s]} = \frac{1}{m_i} dp_i^{[r]}$.

A.2 Mathematical Complements

Here I provide some mathematical complements.

Dynamic attention: Beyond the random walk case Here I expand on Section 7.1, beyond the random cases which made the analytics very transparent. I consider the case (71) with ρ not necessarily equal to 1. The sticky action is a bit more delicate to compute. Consider an agent who can change her action at time t. At period $t+s$, she will still have to perform action $a_{t,s}^{A}=a_{t,0}^{A}$ with probability θ^{s} (we use the Calvo formulation here). Hence, the optimal action at t satisfies

$$\max_{a} -\mathbb{E}_{t}\sum_{s=0}^{\infty}\beta^{s}\theta^{s}\left(a-x_{t+s}\right)^{2}.$$

The first order condition is

$$\mathbb{E}_{t}\sum_{s=0}^{\infty}\beta^{s}\theta^{s}\left(a-x_{t+s}\right)=0$$

i.e. $\frac{1}{1-\beta\theta}a-\sum_{s=0}^{\infty}\beta^{s}\theta^{s}\mathbb{E}_{t}\left[x_{t+s}\right]=0$, i.e. $a=a_{t,0}^{A}$ with

$$a_{t,0}^{A}=\left(1-\beta\theta\right)\mathbb{E}_{t}\sum_{s=0}^{\infty}\beta^{s}\theta^{s}\mathbb{E}_{t}\left[x_{t+s}\right]. \tag{83}$$

In the AR(1) case, $\mathbb{E}_{t}\left[x_{t+s}\right]=\rho^{s}x_{t}$, and

$$a_{t,0}^{A}=\frac{1-\beta\theta}{1-\beta\theta\rho}x_{t}. \tag{84}$$

In the sticky information model, the problem is, for each period t,

$$\max_{a_{t,s}^{I}} -\mathbb{E}_{t-s}\left(a_{t,s}^{I}-x_{t}\right)^{2}$$

which yields

$$a_{t,s}^{I}=\mathbb{E}_{t-s}\left[x_{t}\right]. \tag{85}$$

Hence, we see that the two models are generally different – even though they generate the same predictions in the random walk case.

B Appendix: Data Methodology

This appendix outlines the details of the methodology used to compile the data in Table 1 and Figure 1, which present point estimates of the attention parameter m in a cross-section of recent studies, alongside the estimated relative value of the opaque add-on attribute with respect to the relevant good or quantity (τ/p).

- In the study of Allcott and Wozny (2014), we take τ to be the standard deviation of the present discounted value of future gasoline costs in the authors' sample; p is correspondingly the standard deviation of vehicle price, such that $\tau = \$4,147$ and $p = \$9,845$. The point estimate for m is as reported by the authors.

- Hossain and Morgan (2006) and Brown, Hossain, and Morgan (2010) both conduct a series of paired experiments by selling various goods on eBay and varying the shrouded shipping costs. This setup allows us to deduce the implied degree of inattention, following the same methodology as in DellaVigna (2009). We consider auction pairs in which the auction setup and the sum of reserve price are held constant, while the shipping cost is altered. As in DellaVigna (2009), we assume buyers are bidding their true willingness to pay in eBay's second price auctions, such that their bid is $b = p+m\tau$, where p is the buyer's valuation of the object and τ is the shipping cost. Seller's revenue is $p+(1-m)c$. Under this model, the ratio of the difference in revenues to the difference in shipping costs across the two auction conditions corresponds to the quantity $1-m$.

  The estimates for the attention parameter m in the experiments of Hossain and Morgan (2006) are as reported in DellaVigna (2009). We use the same methodology to derive the analogous estimate for the eBay Taiwan field experiment of Brown, Hossain, and Morgan (2010). The raw implied estimate for the latter experimental setting is negative ($m = -0.43$), as the mean revenue difference between the two auction conditions is greater than the difference in shipping costs. For consistency with the definition of m and in order to account for measurement error, we constrain the final implied estimate of m to the interval $[0, 1]$.

  Given that each estimate of m is inferred from a set of two paired auctions, the value p of the good under auction is defined as average revenue minus shipping costs across the two auction conditions. The value τ of the opaque attribute is analogously defined as the average shipping cost across the two auction conditions.

- For the study of DellaVigna and Pollet (2009) we take τ/p to be the ratio of the standard deviation of abnormal returns at earnings announcement to abnormal returns for the quarter, pooled across all weekdays and computed following the methodology in DellaVigna and Pollet (2009). The quarterly cadence is chosen to match the frequency of earnings announcements in the authors' sample. The return at earnings announcement is for two trading days from the close of the market on the trading day before the earnings announcement to the close of the trading day after the earnings announcement. The standard deviation of the abnormal returns at earnings announcement is 0.0794. The standard deviation of the abnormal returns for the quarter, starting from the close of the market on the trading day before the earnings announcement and continuing to the close of the market on trading day 60 after the announcement, is 0.2651. The estimates for the attention parameter m are as in DellaVigna (2009).

- In the case of Lacetera, Pope, and Sydnor (2012), τ is taken to be the average mileage remainder in the sample, which is approximately $5,000$, per correspondence with the authors. The quantity p is obtained by subtracting $\tau = 5,000$ from the mileage of the median car in the sample, which is $56,997$. Hence $p = 51,997$. The estimate for m is as reported by the authors in the full-sample specification that includes all car transactions, pooled across fleet/lease and dealer categories.

- For the field experiment of Chetty, Looney, and Kroft (2009), we take τ/p to be the relevant sales tax rate of 7.38%. Correspondingly, for the natural experiment of Chetty, Looney, and Kroft (2009) we take τ/p to be 4.30%, which is the mean sales tax rate for alcoholic products across U.S. states as reported by the authors. The estimates for the attention parameter m are as reported by the authors.

- For the study of Taubinsky and Rees-Jones (2017), we analogously let τ/p be the sales tax rate applied in the laboratory experiment, which is 7.31%. The estimate for the attention parameter m is as reported by the authors for the standard-tax sample.

- Figure 1 additionally shows data points from Busse, Lacetera, Pope, Silva-Risso, and Sydnor (2013b), who measure inattention to left-digit remainders in the mileage of used cars in auctions along several covariate dimensions. Each data point corresponds to a subsample of cars with mileages within a 10,000 mile-wide bin (e.g., between 15,000 and 25,000 miles, between 25,000 and 35,000 miles, and so forth). Data is available for two data sets, one including retail auctions and one including wholesale auctions. For each mileage bin, we include data points from both of these data sets. The estimates of m are as reported by the authors. The metric τ/p is the average ratio of mileage remainder to true mileage net of mileage remainder in the subsamples. As this ratio is most readily available for the data set of wholesale car auctions, we compute the τ/p estimates on subsamples of the wholesale data set only, under the assumption that the mileage distribution is not systematically different across the two data sets. We do not expect substantive impact on our results from this assumption.

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