Universidad de la República
Facultad de Ciencias Sociales
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Tesis Doctorado en Economía

Addiction, Decision-Making, and Policy Design: Experimental Studies on Cigarette Packaging

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Introduction

Tobacco consumption is one of the leading causes of preventable morbidity and mortality worldwide. Despite regulatory efforts and public health campaigns, cigarettes remain widely consumed, posing a significant challenge for policymakers. In this context, my doctoral thesis focuses on studying the effects of tobacco control policies and consumer decision-making, with a specific emphasis on cigarette packaging as the experimental object. The three articles are interconnected and demonstrate a progression in the sophistication of analyzed elements, ranging from the impact of plain packaging to the psychological mechanisms influencing smokers' choices. Together, these articles provide empirical evidence and novel perspectives for designing effective public policies.

The first article, "Impact of Plain Packaging of Cigarettes on the Risk Perception of Uruguayan Smokers: An Experimental Study," explores the effects of plain packaging on the risk perception of Uruguayan smokers. Using a choice-based conjoint analysis of package attributes, the study demonstrates that plain packaging significantly increases risk perception, even in a highly regulated environment like Uruguay. This study highlights how removing distinctive brand elements and using colors associated with danger can alter consumer perceptions, reinforcing plain packaging policies as a tobacco control tool. Furthermore, it underscores that in a country with such strict anti-tobacco regulations as Uruguay, packaging has become one of the few remaining instruments available to influence smokers' decisions. The version of the article included in this thesis is exactly the same as the one later published as Harris, J. E., Ares, G., Gerstenblüth, M., & Triunfo, P. (2018). *Impact of plain packaging of cigarettes on the risk perception of Uruguayan smokers: An experimental study. Tobacco Control, 27*(5), 513–518.

The second article, "Addiction and Rational Choice: Evidence from an Eye-Tracking Experiment with Cigarette Packages," investigates smokers' decision-making processes when confronted with cigarette packs featuring graphic warnings and varied designs. Combining eye-tracking technology and discrete choice experiments, the study analyzes how addiction affects decision strategies. The results reveal that smokers tend to use heuristic strategies, such as lexicographic

utility, to minimize cognitive noise, and that these strategies are correlated with their daily cigarette consumption intensity. This underscores the fundamental role of cigarette packaging as a key element in consumer decision-making, providing insights into how its design and regulations can influence rational choices among smokers. This article offers a unique perspective on the role of addiction in rational decision-making and its implications for public health interventions.

The third article, "Top-Down versus Bottom-Up Processing of Cigarette Package Warnings: Experimental Evidence from Uruguay," delves into the psychological mechanisms underlying cigarette package choices, focusing on the interplay between top-down and bottom-up attentional processes. Using an experimental design, the study explores how visual salience and pre-existing preferences influence decision-making. It finds that younger, less addicted participants are more influenced by salient design elements, while older, more addicted individuals rely predominantly on top-down processes driven by entrenched cognitive evaluations. This research highlights the importance of tailoring regulatory strategies to different smoker profiles, suggesting that salience-based interventions may be more effective for younger, less dependent individuals, whereas cognitive and habitual mechanisms dominate decision-making among more addicted populations. These findings provide a nuanced perspective on how addiction moderates the effectiveness of health warnings and visual designs in influencing consumer behavior, offering valuable insights for public health policy.

Together, the three articles in this thesis offer a comprehensive understanding of the effects of tobacco control policies from different angles, highlighting a clear methodological progression across studies and their common focus on cigarette packaging as a critical policy tool. Each article adds new layers of analysis, from risk perception to the psychological mechanisms shaping consumer choices. These findings not only reinforce the effectiveness of existing regulatory interventions but also suggest areas for improvement to design more effective policies targeted at specific consumer groups. Moreover, the use of advanced methodologies such as eye-tracking and lexicographic utility analysis provides a robust empirical foundation and methodological innovation to the field of tobacco control and behavioral economics.

With this thesis, I aim to contribute to advancing knowledge at the intersection of behavioral economics, decision psychology, and public health, providing evidence to guide the implementation of more effective and equitable policies to reduce tobacco consumption and its negative societal impacts.

Impact of Plain Packaging of Cigarettes on the Risk Perception of Uruguayan Smokers: An Experimental Study

Jeffrey E. Harris[1], Gastón Ares[2], Mariana Gerstenblüth[3], Leandro Machin[4], Patricia Triunfo[3]

Abstract

Uruguay, a South American country with 3.4 million inhabitants, has already banned tobacco advertising, prohibited terms such as "light," "mild," and "low-tar," and required graphic warnings covering 80% of cigarette packs. The country is now considering the implementation of plain, standardized packaging. In this context, we conducted an experimental choice-based conjoint analysis to evaluate the impact of alternative cigarette package designs on the risk perceptions of 180 adult Uruguayan smokers. We compared plain packaging, which includes a standardized brand description and the dark brown background color mandated for Australian cigarette packs, to two controls: the current package design with distinctive brand elements and colors, and a modified design retaining the distinctive brand elements but incorporating the dark brown background color. Graphic warnings were also varied across designs. The results showed that plain packaging significantly reduced the likelihood of perceiving the cigarettes as less harmful compared to the current package design and the modified package design. These findings demonstrate that plain packaging enhances the perceived risk of cigarette products even in a highly regulated setting like Uruguay. Both the removal of distinctive brand elements and the use of Australia's dark brown background color contributed to this observed effect.

JEL Classification

I18, D91, C91, M38, H51

Key Words

Cigarettes; plain packaging; choice-based conjoint analysis; health warnings; risk perception; Uruguay

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1. Introduction

Uruguay, a small country in South America with 3.4 million inhabitants, has been on the forefront of tobacco control worldwide since it ratified the Framework Convention on Tobacco Control in 2004 (Abascal et al., 2012). To date, the Uruguayan government has banned smoking in public spaces, increased tobacco taxes, completely prohibited tobacco advertising and promotion, required rotating graphic warnings covering 80% of the front and back of each cigarette package, outlawed such terms as light, mild or low-tar, and banned multiple versions of the same brand, such as Silver, Blue or Lights (Triunfo et al., 2016). Evaluation studies have documented a concomitant decline in cigarette consumption in adults and adolescents, as well as an increase in cessation among pregnant smokers (Abascal et al., 2016; Triunfo et al., 2016; Harris et al., 2015).

The Uruguayan legislature has recently considered the institution of plain, standardized cigarette packaging, a policy that was first implemented in Australia in 2011 (Australian Government, 2011). The contemplated new legislation would replace the current brand presentation, including any distinctive graphics, with a standardized brand name in a uniform font placed in a fixed location on the pack. All distinctive colors would be replaced by the dark brown currently mandated on Australian cigarette packs. Both the text and images of the current rotating warnings would be retained.

In response to a request from the Uruguayan Ministry of Public Health, we performed an experimental study of the impact of the key elements of the contemplated plain-packaging legislation on smokers' perceptions of health risks. Experimental studies of the impact of plain packaging on consumers' perceptions of the health risks have been carried out in Australia, Brazil, France, the United Kingdom, and the United States (Wakefield et al, 2008; Hammond et al., 2009; Germain et al., 2009; Hoek et al., 2011; Bansal-Travers et al., 2011; Doxey & Hammond, 2011; Wakefield et al., 2012; White et al., 2012; Gallopel-Morvan et al., 2012; Hammond et al., 2014; Kotnowski et al., 2016)

However, no such study has been undertaken in the specific population and regulatory setting of Uruguay.

Uruguayan smokers, we find, perceive cigarettes with plain, standardized packages as significantly more harmful. Both the standardized brand name and the uniform package color separately contribute to the perception of increased harm. Our findings support the efficacy of plain packaging to alter smokers' risk perceptions even in a setting where graphic warnings cover 80 percent of the pack and descriptors such as light, mild and low-tar have been prohibited.

2. Methods

We employed choice-based conjoint (CBC) analysis, a methodology developed in the early 1970s to decompose consumers' preferences for products into components attributable to individual product characteristics. While CBC analysis has been used primarily to analyze purchasing preferences, it has also been employed to study consumers' perceptions about products, including included healthfulness (Vidal et al., 2016), degree of masculinity or femininity (Green & DeSerbo, 1978), and customer satisfaction (Schaupp & Bélanger, 2005). Here, we apply CBC analysis to smokers' perceptions of health risks of different experimental brands of cigarettes.

Product Attributes

We focused on three specific attributes of the cigarette package: the color, the warning, and the packaging.

Color. We specified two alternative levels for the color attribute. For the first color level, we chose combination of white and blue typical of the packages of branded cigarettes marketed in Uruguay. In a study of U.S. smokers, whiter packaging was found to connote greater safety (Bansal-Travers et al., 2011). We refer to this alternative as the *white and blue color*. For the second color level, we chose the dark brown color designated as Pantone 448C in Australia's 2011 plain packaging regulations (Australian Government, 2011). This color (equivalent to C 0, M 22, Y 85, K 85) was identified in a study of Australian smokers as implying the greatest harm (Parr et al., 2011a; Parr et al 2011b). We refer to this alternative as the *dark brown color*.

Warning. We specified two alternative levels for the warning attribute. Each alternative contained an image and text, and was chosen from the public database maintained by the Comisión Intergubernamental para el Control del Tabaco del MERCOSUR (CICT). For the first warning, we chose a symbolic, optimistic message depicting a boot stamping out cigarettes, with the accompanying text, "Take the first step today. It's possible to quit smoking." We refer to this alternative as the *boot warning*. For the second warning, we chose a concrete, negative message depicting an oral cancer, with the accompanying text, "Smoking causes bad breath, tooth loss and cancer of the mouth." We refer to this alternative as the *mouth warning*. In preliminary testing of multiple warnings, we found these two alternatives to lie at the extremes of the spectrum of risk perception.

Packaging. We specified three alternative levels for the packaging attribute. For the first alternative, we specified a fictitious brand name with distinctive logo and typography, accompanied by the white and blue color scheme. This level was intended to mirror the design of packages of branded cigarettes currently marketed in Uruguay. We refer to this alternative as *current packaging*. For the second alternative, we retained the same fictitious brand name with distinctive logo and typography, but substituted the dark brown color. We refer to this alternative as *current packaging with modified color*, or *modified packaging* for short. For the third alternative, we removed the distinctive logo and typography of the fictitious brand, moved the brand name to the bottom of the package, and retained the dark brown color. We refer to this alternative as *plain packaging*.

Figure 1 shows the three alternative packages with the boot warning. Figure 2 shows the same three alternative packages with the mouth warning.

Current Packaging | Current with Modified Color | Plain Packaging

Figure 1. Three alternative packages with the boot warning. The text reads, "Take the first step today. It's possible to quit smoking."

Current Packaging | Current with Modified Color | Plain Packaging

Figure 2. Three alternative packages with the mouth warning. The text reads, "Smoking causes bad breath, tooth loss and cancer of the mouth."

Two Experimental Designs

We specified two separate experimental designs. Design 1 compared plain packaging to current packaging. Design 2 compared plain packaging to current packaging with modified color. Design 1 tested the combined effect of the change in color and the elimination of distinctive brand elements. Design 2 isolated the effect of a change in color alone.

For each of the designs, we thus had a 2×2 factorial experiment with four product profiles. In Design 1, the four profiles were: plain packaging with boot warning (Figure 1, far right); plain packaging and mouth warning (Figure 2, far right); current packaging with boot warning (Figure 1, far left); and current packaging with mouth warning (Figure 2, far right). Similarly, in Design 2, the four profiles were: plain packaging with boot warning (Figure 1, far right); plain packaging with mouth warning (Figure 2, far right); current packaging with modified color and boot warning (Figure 1, middle); and current packaging with modified color and mouth warning (Figure 2, middle).

Choice Sets

For each of the two experimental designs, participants were confronted with a series of binary choices among pairs of the four possible product profiles. We used the mix-and-max procedure (Johnson et al., 2007) to select these binary choice sets in order to create a balanced design. The eleven choice sets that we employed in our study are shown in Figure 3. Five choice sets were applicable solely to Design 1, while five choice sets were applicable solely to Design 2. One choice set (Set 6), which entailed a comparison of plain packaging with the mouth warning to plain packaging with the boot warning, was applicable to both experimental designs.

Set	Left Profile	Right Profile	Design
1	Current Boot 	Plain Boot 	1
2	Modified Boot 	Plain Boot 	2
3	Current Mouth 	Plain Boot 	1
4	Modified Mouth 	Plain Boot 	2
5	Plain Mouth 	Plain Boot 	Both
6	Current Boot 	Plain Mouth 	1
7	Modified Boot 	Plain Mouth 	2
8	Current Boot 	Current Mouth 	1
9	Modified Boot 	Modified Mouth 	2
10	Plain Mouth 	Current Mouth 	1
11	Plain Mouth 	Modified Mouth 	2

Figure 3. Choice Sets for the Two Experimental Designs. "Modified" refers to the current package with modified color. Choice Set 5 was applicable to both Design 1 and Design 2. In half of the subjects, the left-right positioning of the product profiles was as shown above. In the other half, the positioning was reversed. The ordering of choice sets was randomized among all subjects.

Subjects

A convenience sample of 180 self-reported adult current smokers was recruited principally from the faculty, students and employees of the University of the Republic in Montevideo, Uruguay. Table 1 shows the descriptive statistics for the 164 participants for whom we had complete data on demographic characteristics and smoking habits. The sample was evenly balanced by sex, and the average age was 36.2 with a range of 19–65 years. Three out of four participants had some university education. Forty percent of participants displayed the lowest level of nicotine dependence according to the short Fagerstrom criteria performed by Heatherton et al. (1991) (10 or fewer cigarettes per day, more than 1 hour elapsed from arising in the morning to smoking one's first cigarette). Two-thirds of participants had made a serious attempt to quit smoking in the past year.

Table 1. Descriptive Statistics on Study Participants*

Variable	Mean	Standard Deviation	Range
Female (%)	50.0	50.1	
Age (years)	36.2	11.3	19–65
Education Attained:			
Primary Only (%)	1.2		
Some High School (%)	8.5		
Completed High School (%)	6.7		
Technical Education (%)	9.8		
Some University (%)	37.2		
Graduated University (%)	14.0		
Graduate Study (%)	22.6		
Cigarettes Smoked per Day:			
1–10 (%)	55.5		
11–20 (%)	32.3		
21–30 (%)	10.4		
> 30 (%)	1.8		
Time to First Cigarette upon Arising in a.m.:			
0–5 minutes (%)	6.1		
6–30 minutes (%)	27.4		
30 minutes – 1 hour (%)	18.9		
> 1 hour (%)	47.6		
Tried Seriously to Quit During Past Year (%)	67.7	46.9	

*All participants were self-reported current cigarette smokers.

Experimental Procedure

Recruited subjects participated online. Each subject was shown a series of 11 screens, each containing one of the binary choice sets listed in Figure 3. In half of the subjects, the left-right positioning of the product profiles was as shown in the Figure. In the other half, the positioning was reversed. The ordering of choice sets was randomized among all subjects. Subjects were also asked questions about smoking habits and demographics.

For each choice set, the participant was instructed to look at the screen and choose which of the two packs he considered to be *less* risky for his health. The no-choice option was unavailable. That is, participants had to choose one of the two options on each screen.

Statistical Analysis

We employed conditional logit regression (McFadden, 1974) to analyze the data derived from our CBC study. We analyzed the data from Designs 1 and 2 separately. In each conditional logit model, there were $180 \times 6 = 1{,}080$ observations, that is, 6 binary choices for each of the 180 participants. In each model, the dependent variable was the product profile designated as less risky, while the independent variables were the warning (mouth versus boot), the packaging (plain versus current packaging in Design 1, plain versus current packaging with modified color in Design 2), and the position of the product on the screen (left versus right). We included the latter variable because Uruguayans, as readers of Spanish, tend to scan from left to right.

We used two procedures to test the 2-sided null hypothesis that the coefficient of plain versus current packaging in Design 1 was equal to the coefficient of plain versus modified packaging in Design 2. In the first procedure, more conservative procedure, we used a Z-test to compare the coefficients derived from the two separate logit regressions. In the second, we ran the conditional logit model on the pooled data from Designs 1 and 2, directly testing the contrast between the coefficients of plain packaging in the two designs. This second procedure assumed that the coefficients of boot versus mouth warning and left versus right position were equal in the two designs.

Finally, we ran conditional logit models on subsets of the study population based upon the demographic and smoking characteristics shown in Table 1.

3. Results

Tables 2 and 3 show the conditional logit regression results for Designs 1 and 2, respectively. In both designs, the coefficient of the boot versus the mouth warning was significantly positive, indicating that boot warning significantly *reduced* the perceived riskiness of the product in comparison to the mouth warning. Equivalently, the mouth warning significantly *increased* the perceived health risk in comparison to the boot warning.

Table 2. Conditional Logit Regression Results for Experimental Design 1 [a]

Independent Variable	Coefficient [b]	Odds Ratio [b]
Boot (versus Mouth)	1.425 (1.229 to 1.621)	4.158 (3.418 to 5.056)
Plain Packaging (versus Current Packaging)	–0.920 (–1.098 to –0.742)	0.398 (0.333 to 0.476)
Left Position (versus Right)	–0.256 (–0.406 to –0.106)	0.774 (0.666 to 0.899)
Number of Observations [c]	1,080	
Pseudo R^2	0.235	

a. Dependent variable was the product perceived as less risky.
b. Numbers in parentheses correspond to 95% confidence intervals. Estimated coefficient of Left Position significant at level $p = 0.001$. Estimated coefficients of Boot and Plain Packaging significant at level $p < 0.001$.
c. Number of binary choices, equal to 6 choices for each of 180 participants.

Table 3. Conditional Logit Regression Results for Experimental Design 2 [a]

Independent Variable	Coefficient [b]	Odds Ratio [b]
Boot (versus Mouth)	1.592 (1.389 to 1.795)	4.912 (4.009 to 6.019)
Plain Packaging (versus Modified Packaging)	–0.678 (–0.852 to –0.503)	0.508 (0.426 to 0.605)
Left Position (versus Right)	–0.316 (–0.468 to –0.164)	0.729 (0.626 to 0.849)
Number of Observations	1,080	
Pseudo R^2	0.243	

a. Dependent variable was the product perceived as less risky.
b. Numbers in parentheses correspond to 95% confidence intervals. All estimated coefficients significant at level $p < 0.001$.
c. Number of binary choices, equal to 6 choices for each of 180 participants.

In both Tables 2 and 3, the coefficients of plain packaging were significantly negative, indicating the plain packing *increased* the perceived health risk in comparison with the alternative packaging. In Design 1 (Table 2), the coefficient of plain versus current packaging was –0.920 (95% confidence interval, –1.098 to –0.742), while in Design 2 (Table 3), the coefficient of plain modified packaging was –0.678 (95% confidence interval, –0.852 to –0.503). Based upon the conservative two-sided Z-test, we rejected the null hypothesis that these two coefficients were equal at the significance level $p = 0.057$. Based upon the pooled data, the estimated difference between the two coefficients, that is, the effect of plain packaging in Design 2 versus Design 1, was 0.285 (95% confidence interval, 0.038 to 0.532, $p = 0.024$). Finally, Tables 2 and 3 revealed relatively small effects of positioning. In particular, positioning of a product profile on the left side of the screening increased the perceived health risk in comparison to positioning on the right side.

In both Designs 1 and 2, the coefficients of plain packaging were significantly different from zero ($p < 0.02$) in all subsets defined by gender, age (less than 35 years, 35 years or more), education (less than university graduate, university graduate or more), short Fagerstrom criteria for nicotine dependence (lowest level, all other), and serious attempt to quit smoking in the past year (at least one attempt, none). The coefficients of plain packaging were significantly more negative in those subjects who had made a serious attempt to quit smoking in the past year

(Design 1: –1.308 compared to –0.466, $p < 0.001$; Design 2: –0.898 compared to –0.368, $p = 0.007$). Otherwise, the effects of plain packaging on risk perception were indistinguishable between subgroups.

4. Discussion

In a choice-based conjoint study of experimental cigarette brands, we found that plain packaging increased the perceived health risks reported by participating Uruguayan smokers. In our first experimental design (Design 1), we measured the increase in perceived risk attributable to the combination of two changes, the replacement of the distinctive branding elements with a standardized brand name, and the replacement of the distinctive white and blue color with the Australian dark brown color. In our second design (Design 2), we measured the increase in perceived risk attributable solely to the replacement of the white and blue color with the dark brown color. We found the Design-1 effect to be significantly larger than the Design-2 effect. This finding supports the conclusion that increase in perceived risk attributable to the combined elimination of distinctive branding elements and distinctive color exceeded the increase in perceived risk attributable solely to the elimination of the distinctive color.

Our study supports the conclusion that plain packaging enhances the perceived risk of cigarette products even in a regulatory setting such as Uruguay, where tobacco advertising has been completely prohibited, where brand descriptors such as light, mild and low-tar have been banned, and where warnings with text and graphic elements cover 80% of the cigarette package.

Finally, we observed an effect of plain packaging on perceived risk in all subsets of study participants defined by smoking habits and demographics. The estimated impacts of plain packaging on perceived risk were significantly greater in subjects who had reported making at least one serious attempt to quit smoking in the past year.

Study Advantages

An important advantage of this study is its use of experimental stimuli that matched the specific features of currently contemplated plain packaging legislation. The packages presented to participants (Figures 1 and 2) contained warnings with text and graphics covering 80% of the front surface, a requirement for cigarettes marketed in Uruguay. Some prior experimental studies, by contrast, utilized warnings with smaller images (White et al., 2008) or no images (White et al., 2012; Gallopel-Morvan et al., 2012). Our study specifically used the dark brown color mandated in Australia, whereas some prior studies employed other background colors, including gray (Gallopel-Morvan et al., 2012).

Some prior studies have employed a cross-sectional design, in which each subject was asked to evaluate a single experimental stimulus (Wakefield et al., 2008; Germain et al., 2010; Wakefield et al., 2012). Following other studies (Hoek et al., 2011; Bansal-Travers et al., 2011; Gallopel-Morvan et al., 2012; Hammond et al., 2014) we employed a choice-based experimental design that more closely mimicked real choices among packages. In our study, we observed a significant gradient of response, in which plain packaging evoked a greater perception of health risk than current packaging modified to eliminate distinctive brand colors, which in turn evoked a greater perception of health risk than current packaging. Some studies, by contrast, were not designed to measure a gradient of response, and still others did not observe a significant gradient even when they were designed to detect one (Doxey & Hammond, 2011; White et al., 2012; Hammond et al., 2014; Kotnowski et al., 2016).

Study Limitations

Our study has several limitations. First, our experimental subjects were recruited principally from a university environment. On average, they appeared to be more educated and less nicotine-dependent than the general population of Uruguayan smokers. Our findings need to be replicated on a more representative panel.

Second, our sole endpoint was the perceived health risk of various cigarette package presentations. Our results may not be generalizable to purchase decisions or to attempts to quit smoking (Hammond et al., 2009; Hoek et al., 2011; Bansal-Travers

et al., 2011; Gallopel-Morvan et al., 2012; Hammond & Parkinson, 2009). Third, we focused on adult smokers. Our analysis does not address the perceptions of adolescents who are at risk of becoming regular smokers (Hammond et al., 2009; White et al., 2012; Hammond et al., 2014; Kotnowski et al., 2016). Fourth, our study provides evidence that the institution of plain packaging may prove effective in an already highly regulated setting such as Uruguay, but it does not demonstrate conclusively that plain packaging will in fact reduce cigarette consumption. If the Uruguayan legislature approves plain packaging legislation, evaluation studies of the type already in progress in Australia will be required.

5. Conclusions

Our study demonstrated that plain packaging enhances the perceived risk of cigarette products even in a highly regulated setting such as Uruguay, where tobacco advertising has been completely prohibited, where light, mild, low-tar and similar brand descriptors have been banned, and where warnings with text and graphic elements are required to cover 80% of the cigarette package.

What this paper adds

- This experimental study was specifically designed to assess the provisions of currently contemplated plain packaging legislation in Uruguay, a South American country of 3.4 million inhabitants that has already instituted strong tobacco control measures.
- Plain packaging significantly enhances the perceived risk of cigarette products even in a highly regulated setting such as Uruguay, where tobacco advertising has been prohibited, where light, mild, low-tar and similar brand descriptors have been banned, and where graphic warnings already cover 80% of the cigarette package.
- Both the elimination of distinctive brand elements and the imposition of the Australian dark brown color contributed to the observed effect on risk perception.

- The impact of plain packaging on perceived health risk was observed in all subsets of participants based on demographics and smoking habits. The impact was significantly greater in subjects who had made a serious attempt to quit smoking during the past year.

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Ethics approval

This study protocol was approved by the Ethics Committee of the School of Chemistry of the Universidad de la República, Uruguay.

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Addiction and Rational Choice: Evidence from an Eye Tracking Experiment with Cigarette Packages

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Abstract

We asked 97 current cigarette smokers to make 12 binary choices between experimental packages with varying warnings and background colors. Participants had to decide which of the two packages contained cigarettes less risky for their health. Confronted with repugnant, threatening images, these smokers nonetheless made choices that were context independent, adhered to transitivity, and consistent with an additive utility model. Eye tracking measurements confirmed that the choices of 65 percent of participants were further compatible with a noise-reducing lexicographic utility model. This subset of participants smoked significantly more cigarettes per day. Our findings support a model in which addiction permits the smoker to suppress aversive stimuli and negative emotions that would otherwise interfere with short-term rational decision making.

JEL Classification

D12, D83, D87, D91, I12, M31

Key Words

Addiction; rational choice; repugnance; aversive stimuli; noise-reducing heuristics; discrete choice experiment; eye tracking

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1. Introduction

It has been frequently observed that aversive stimuli and negative emotions interfere with rational decision-making (Bechara et al., 1999; De Martino et al., 2006; Guclu et al., 2012; Hewig et al., 2011; Leith & Baumeister, 1996; Lerner et al., 2004; Luce, 1998). Whether this general observation similarly applies to cigarette smokers is complicated by their addiction, which itself may influence rational choice. We designed an experiment to sort out the role of addiction as a potentially confounding factor. We asked current smokers to repeatedly choose which of two experimental cigarette packages with varying warnings and background colors was less risky. We determined whether each subject's binary responses adhered to the axioms of rational choice, and whether the extent of any violations of the axioms was related to the subject's degree of addiction. We supplemented our binary choice data with measurements of subject's eye movements and time to response.

Confronted with repugnant, threatening images – which included a dead fetus, a cadaver, and an ulcerated tumor – participating smokers, we found, nonetheless made choices that were context independent, adhered to transitivity, and consistent with an additive utility model. Eye tracking measurements confirmed that the choices of 65 percent of participants were further compatible with a noise-reducing lexicographic utility model. This subset of participants smoked significantly more cigarettes per day. Our findings support a model in which addiction permits the smoker to suppress aversive stimuli and negative emotions that would otherwise interfere with short-term rational decision making.

2. Experimental Design

Participants

We recruited a convenience sample of 98 self-reported adult current cigarette smokers aged 19–60 years from the students, faculty and staff of the Universidad de la República in Montevideo, Uruguay. Details concerning the 97 participants who completed the entire experiment are reported in Appendix 1

Experimental Task

Based on prior work (Harris et al., 2018), we designed an experimental task consisting of a series of 12 predetermined choice sets shown consecutively on a computer screen. Each *choice set* contained images of two cigarette packs, each varying in design along two dimensions: the *warning*, which consisted of an image and accompanying text; and the background *color*. For each choice set, the participant was asked to click on the pack that was "less risky for your health." We adopted a forced-choice design. There was no time limit to make a choice.

Among the 97 smokers who completed the entire experiment, 52 were randomly assigned to Group I, while the remaining 47 subjects were randomly assigned to Group II. Participants in both groups were exposed to the same 12 choice sets in random order, but the right-left orientation of the two packs in each computer screen shown to Group II was the reverse of that shown to Group I. Here, we have labeled the twelve choice sets A through L. Figure 1 specifically shows choice sets D and K displayed to the 52 participants randomized to Group I.

Figure 1. Choice sets D and K shown to participants in Group I.

In set D, the warning on the left contained the image of a fetus held in a gloved hand, accompanied by the text, “Smoking during pregnancy harms the health of your baby.” The warning on the right showed a tagged cadaver with the text, “Smoking causes heart attack.” In set K, the warning on the left showed a boot stamping out cigarettes with the text, “Take the first step today. It’s possible to quit smoking.” The warning on the right showed ulcerated mouth tumor accompanied by the text, “Smoking causes bad breath, tooth loss and cancer of the mouth.” All warnings were selected from an image repository (CICT, 2016) and had not appeared on any cigarettes marketed in Uruguay.

Each pack had one of three background colors: gray, light brown, or dark brown. The packs on the right in screens D and K have a gray background color, while the pack on the left in screen D has a light brown background and the pack on the left in screen K has a dark brown background. The latter background color has long been mandated on all packages of cigarettes sold in Australia (Australian Government, 2011). In a study of Australian smokers that included these three background colors, dark brown was found to imply the greatest harm (Parr et al., 2011). Aside from the warning and the background color, all cigarette packs conformed to prevailing requirements of plain packaging in effect in Australia, France, the United Kingdom, New Zealand and Norway (Australian Government, 2011; Moodie et al., 2018) and recently enacted in Uruguay. Every pack shown to a participant was a combination of one of the three images (fetus, cadaver, boot) and one of the three colors (light brown, dark brown, gray).Table 1 shows the 12 choice sets shown to the 52 participants randomized to Group I.

Table 1. Choice Sets shown to participants in Group I*

Screen	Package on the Left	Package on the Right
A	Mouth, Dark Brown	Cadaver, Dark Brown
B	Fetus, Dark Brown	Fetus, Light Brown
C	Cadaver, Light Brown	Boot, Light Brown
D	Fetus, Light Brown	Cadaver, Gray
E	Mouth, Gray	Boot, Dark Brown
F	Boot, Gray	Fetus, Gray
G	Cadaver, Light Brown	Cadaver, Dark Brown
H	Fetus, Gray	Fetus, Dark Brown
I	Cadaver, Gray	Mouth, Dark Brown
J	Boot, Light Brown	Mouth, Light Brown
K	Boot, Dark Brown	Mouth, Gray
L	Mouth, Light Brown	Boot, Gray

*Participants in Group II were shown the same choice sets, but with the right and left packages reversed. The 12 choice sets were generated by the mix-and-match procedure.

Eye Tracking

We used eye tracking technology to assess the timing and sequence of participants' eye fixations on five mutually exclusive areas within each package: the warning image, the warning text, the lateral text, the toxic-product symbol, and the brand name. Details of our eye tracking methodology are given in Appendix 2.

Semi-Structured Interview

At the completion of the 12-set task, participants were shown a diagram of their fixations for two of the choice sets and then asked to respond to the following questions: Why do you think you looked at those areas? How did you select the pack that was less risky for your health?

3. Tests of Rational Choice

Our fundamental objects of choice are cigarette *packages*. Each package has two attributes: its *warning* w, an element of the set $W = \{Boot, Cadaver, Fetus, Mouth\}$; and its *background color* b, an element of the set $B = \{Gray, Light\ Brown, Dark\ Brown\}$. The set of packages is $X = W \times B$ with arbitrary element $x = (w, b) \in X$. At each successive computer screen, each cigarette smoker had to choose the less risky package from a binary *choice set* $S = \{x, x'\}$, where $x, x' \in X$ and $x \neq x'$. We studied whether the observed choices adhered to the following properties.

Context Independence. Under *context independence*, a subject confronted with the same choice set $S = \{x, x'\}$ at two different points in the experiment will consistently choose the same package over the other. If the participant instead chooses x at one point but subsequently opts for x', his choices must depend on some contextual element that has changed. Such a finding would undermine the notion of "simple scalability" that an individual's preference between packages x and x' depends solely on their comparative perceived riskiness or, more generally, on their comparative *utility* (Tversky, 1972).

There is considerable experimental evidence that individual preferences do change during the course of an experiment (Alós-Ferrer and Garagnani 2022; Hey, 2001) and that preferences are in fact context-dependent (Tversky & Simonson, 1993). In some experiments, an individual's preference for x versus x' depends on the presence or absence of a third option x'' in the choice set, often referred to as a decoy (Rooderkerk et al., 2011; Trueblood et al., 2013). Still, context dependence can be detected even in binary choice experiments such as ours.

There are two natural contextual elements in our experimental design. When the right-left positioning of a package influences smokers' choices, we'll say that their preferences exhibit a *positioning effect* (Ryan et al., 2018). When the order of presentation of a choice set influences smokers' choices, we'll say that their preferences exhibit an *ordering effect*. Such an effect may be important when there is learning or fatigue during the course of the experiment (Campbell et al., 2015; Czajkowsk et al., 2014; Day et al., 2012).

Transitivity. Consider a smoker who chooses package x as less risky than package x' and who also chooses package x' as less risky than package x''. *Transitivity* requires that the subject choose package x as less risky than package x''. In addition to context independence, transitivity is the other key property establishing that the smoker's preferences can be represented by a *utility function* $u(x)$ for each element x in a finite set X of packages. For example, if we regard higher utility as meaning less risky, we can represent the smoker's preferences in this case by a utility function with values $u(x) = 3, u(x') = 2$ and $u(x'') = 1$. Violations of transitivity result in preference cycles, which have repeatedly been observed in some but not all experimental settings (Birnbaum & Bahra, 2012; Birnbaum et al., 2016; Tversky, 1969).

Additive Utility. A smoker's choices are consistent with *additive utility* if they can be represented by a utility function of the form $u(x) = u(w, b) = u_W(w) + u_B(b)$, where $u_W(w)$ is a *warning utility* function on the set W and $u_B(b)$ is a *background-color utility* function on the set B. Additive utility allows for *compensatory* decision making. Thus, a smoker with additive utility perceives package $x = (w, b)$ as less risky than package $x' = (w', b')$ when $u_W(w) + u_B(b) > u_W(w') + u_B(b')$. So, even if the warning utility of the latter package x' is higher, that is, $u_W(w) + u_W(w') < 0$, the smoker will still choose the former package x so long as its background utility is sufficiently large to compensate, that is, so long as $\big(u_B(b) - u_B(b')\big) + \big(u_W(w) - u_W(w')\big) > 0$.

Lexicographic Utility. Smokers' choices are consistent with *lexicographic utility* when their decision making is *non-compensatory* (Dhami & Mandel, 2013; Dieckmann et al., 2009; van de Kaa, 2017). That is, smokers compare two packages solely on the basis of their warnings and relies on their background colors only when the two packages have equally risky warnings. In view of our research findings, we do not formalize the opposite case where the smoker compares two packages based on their background colors and only on their warnings when they have an equally risky color.

More formally, they choose package $x = (w, b)$ over package $x' = (w', b')$ when either: (i)$u_W(w) > u_W(w')$; or (ii) $u_W(w) = u_W(w')$ and $u_B(b) \geq u_B(b')$.

A smoker with additive utility evaluates both $u_W(w) - u_W(w')$ and $u_B(b) - u_B(b')$. Noisy errors in either utility differential can alter the smoker's choice. By contrast, in the case of lexicographic utility where $u_W(w) \neq u_W(w')$, the smoker assesses only $u_W(w) - u_W(w')$. Noisy errors in the term $u_B(b) - u_B(b')$ do not matter. In this sense, a lexicographic utility function operates as a *noise-reducing heuristic* (Dhami & Harries, 2010).

4. Results

Context Independence

Choice set E shows the package $x = (Mouth, Gray)$ on the left and the package $x' = (Boot, Dark\ Brown)$ on the right, while choice set K shows the same packages x and x' with their right-left orientation reversed. Context independence would require that a participant consistently chose X or X'. In fact, as shown in row 1 of Table 2,93 out of 97 participants gave responses compatible with context independence. Among the 93 participants with context-independent preferences, 89 (95.7%) consistently chose $(Boot, Dark\ Brown)$ over $(Mouth, Grey)$.

Transitivity / Additive Utility

Choice sets A, C and J were shown to participants assigned to Group I. In set A, smokers choose between $(Mouth, Dark\ Brown)$ on the left and $(Cadaver, Dark\ Brown)$ on the right. Under an additive utility model, their choice will depend only on the relative values of $u_W(Mouth)$ and $u_W(Cadaver)$, as both packages have the same background color. Likewise, under an additive utility model, the choice in set C will depend only on the relative values of $u_W(Cadaver)$ and $u_W(Boot)$, while the choice in set J will depend only on the relative values of $u_W(Boot)$ and $u_W(Mouth)$.

Comparison of the smoker's choices in sets A, C and J constitutes a test of transitivity. For example, if the smoker chooses the package on the right in set A, then $u_W(Cadaver) > u_W(Mouth)$, and chooses the package on the right in set C, then $u_W(Boot) > u_W(Cadaver)$. These two choices imply $u_W(Boot) > u_W(Mouth)$. Thus, transitivity would require that the smoker chooses the package

on the left in set J. In fact, as shown in row 2 in Table 2 above, all 97 participants made choices among screens A, C and J that were consistent with transitivity in an additive utility model. The most common implied ordering was $u_W(Boot) > u_W(Cadaver) > u_W(Mouth)$, observed in 55 (56.7 percent) of participants.

Table 2. Tests of Context Independence, Transitivity, Addictive Utility and Lexicographic Utility

Test	Sets	Package on Left	Package on Right	Condition	*N**	%
1	E	Mouth, Gray	Boot, Dark Brown	Context	93	96
	K	Boot, Dark Brown	Mouth, Gray	Independence		
2	A	Cadaver, Dark Brown	Mouth, Dark Brown	Transitivity,	97	100
	C	Boot, Light Brown	Cadaver, Light Brown	Additive utility		
	J	Mouth, Light Brown	Boot, Light Brown			
3	A	Mouth, Dark Brown	Cadaver, Dark Brown	Lexicographic	89	92
	I	Cadaver, Gray	Mouth, Dark Brown	utility		
4	E	Mouth, Gray	Boot, Dark Brown	Lexicographic	88	91
	J	Boot, Light Brown	Mouth, Light Brown	utility		
	K	Boot, Dark Brown	Mouth, Gray			
	L	Mouth, Dark Brown	Boot, Gray			
5	C	Boot, Light Brown	Cadaver, Light Brown	Transitivity,	91	94
	D	Fetus, Light Brown	Cadaver, Gray	lexicographic		
	F	Boot, Gray	Fetus, Gray	utility		
6	B	Fetus, Dark Brown	Fetus, Light Brown	Lexicographic	77	79
	G	Cadaver, Light Brown	Cadaver, Dark Brown	utility		
1–6					63	65

*N = Number of participants whose choices satisfied each specific test. There were 97 total participants. A total of 63 participants satisfied all 6 tests.

Semi-structured Interviews

In the semi-structured interviews at the end of the experimental task, 52 (53.6%) of the 97 participants described the images of the fetus, cadaver and mouth tumor as frightening ("espantosa"), disgusting ("asquerosa"), horrible ("horrible"), severe ("fuerte"), scary ("me dio miedo"), difficult to look at ("complicado ver"), or astonishing ("me dio mucha impresión"). Said one participant, "The image of that mouth is so disgusting that I didn't want to see it." ("La imagen de la boca me da un asco que no quise verla.") Said another, "The image of the baby astonishes me.

I can't even look at it." ("Me da mucha impresión la imagen del bebé. No la puedo ni mirar.") Yet another said, "I think the image of the dead feet is severe, but the mouth is disgusting." ("Yo creo que la imagen de los pies muertos es fuerte, pero la de la boca es asquerosa.")

The participants employed an array of self-protective strategies to suppress these aversive stimuli. In an illustration of the strategy of self-exempting denial (Chapman et al., 1993), one participant commented, "The image is impressive, but I feel that these things won't happen to me, so they don't even affect me." ("Te da una impresión esa imagen, pero creo que son cosas que a mi no me van a pasar, entonces ni me afectan.") Another similarly commented, "What happens to me is that I'm not going to get these diseases, or at least for many years, so they don't affect me." ("Lo que me pasa es que esas enfermedades no me van a pasar, o por lo menos no dentro de muchos años, así que ni me afectan.") In an illustration of the masking strategy, one participant said, "I always cover the images, and that way I pass over them rapidly." ("Yo siempre tapo las imágenes, por eso las pasé rápido.") And another said, "When I buy a pack, I cover it. I don't even look at it." (Yo cuando compro una caja la tapo. Ni la miro.") And still another said, "I always looked the other way." ("Siempre miré para el otro lado.")

Many participants noted that they took account of the background color only when both packages had the same warning. Said one participant, "When I saw two images were the same, I went with the lighter color." ("Cuando veía dos imágenes iguales, me guiaba por el color más clarito.") Said another, "I was guided by all the images, by the photo. In case they were the same, I focused on the colors and chose the lighter color." ("Me guié en todas las imágenes, por la foto. En las que era igual, me fijaba en los colores y elegía el color más claro.")

Lexicographic Utility

Choice sets A and I were displayed to the 52 participants in Group I. If a smoker with lexicographic utility chooses $(Cadaver, Dark\ Brown)$ on the right in set A, he/she will choose $(Cadaver, Gray)$ on the left in set I, even though the two packages have different background colors. Similarly, if he/she chooses $(Mouth, Dark\ Brown)$ on the left in set A, he/she will also choose that package

when it appears on the right in set I. In fact, as shown in row 3 in Table 2 above, 89 (91.8 percent) of our 97 participants made choices consistent with lexicographic utility. Among these 89 participants, 77 (86.5%) chose the package with the cadaver warning in both sets.

Each of E, J, K, and L choice sets, , paired a package with a boot warning to a package with a mouth warning. A smoker who has lexicographic utility, will consistently choose either the package with the boot warning or the package with the mouth warning in all four choice sets. As shown in row 4 in Table 2, 88 (90.7%) of the 97 smokers made choices among these four sets that were consistent with lexicographic utility. Among these 88 smokers, 85 (96.6%) preferred the packages with the boot warnings.

If a smoker has lexicographic utility, his/her choices among the three sets C, D and F should display a transitive ordering among the boot, cadaver and fetus warnings that is independent of the background colors of the packages. As shown in row 5 in Table 2, 91 (or 93.8%) of the 97 smokers made choices among these three sets that were consistent with lexicographic utility. The most common implied ordering was $u_W(Boot) > u_W(Cadaver) > u_W(Fetus)$, observed in 54 (59.3 percent) of the 91 smokers who made choices consistent with lexicographic preferences among the three choice sets.

The comparison between sets B and G addresses participants' preferences for background colors when both packages in a choice set have the same warning. A smoker with lexicographic utility that chooses $(Fetus, Light\ Brown)$ on the right side in set B, would be expected to choose $(Cadaver, Light\ Brown)$ on the left side of set G. As shown in the row 6 of Table 2, 77 (79.4%) of 97 participants gave responses consistent with lexicographic preferences.

Finally, as indicated in the last row of Table 2, 63 (64.9%) of the 97 smokers passed all six tests combined, while 34 (35.1%) failed one or more tests.

Conditional Logit Regressions

We also subjected our choice data to conditional logit regression, based on the extended additive utility model $u_W(w) + u_B(b) + u_M(m) + u_N(n)$, where the additional utility component $u_M(m)$, with $m \in M = \{Left, Right\}$, captures the

participant's tendency to choose a package situated on one side of the computer screen, while the component $u_N(n)$, with $n \in N = \{1, \ldots, 12\}$, captures the sequence number of the choice set. Table 3 shows the results only for the three utility terms $u_W(w)$, $u_B(b)$ and $u_M(m)$, as no significant ordering effects were detected.[7]

Table 3. Conditional Logit Regression estimates

INDEPENDENT VARIABLE	MODEL 1	MODEL 2	MODEL 3
Cadaver	–1.096	–1.112	–1.332
	(0.177)	(0.174)	(0.175)
Fetus	–2.711		
	(0.266)		
Mouth	–2.864		
	(0.162)		
Fetus or Mouth		–2.835	–2.752
		(0.152)	(0.149)
Light Brown	0.707	0.745	
	(0.178)	(0.164)	
Dark Brown	–0.507	–0.490	–0.825
	(0.139)	(0.134)	(0.110)
Right Side	0.209	0.209	0.201
	(0.082)	(0.082)	(0.081)

*All models had 1,164 observations on 97 participants. Numbers in parenthesis below each parameter estimate are standard errors.

In model 1, the omitted reference category for the warnings was the boot, that is, $u_W(Boot) = 0$. Accordingly, the estimated utility component for the cadaver warning, relative to the boot warning, was $\hat{u}_W(Cadaver) = -1{,}096$. The negative sign means that the cadaver warning was perceived as *more risky* than the reference boot warning. The omitted category for the background colors was gray, that is,

[7] We ran our conditional logit models with additional right-hand-side variables representing the sequence order n, either as a continuous variable or as fixed effects. We further tested interactions between sequence order and the other utility components of the model. We also ran our models on subsets of the database partitioned by sequence number. In no case did we find evidence of a significant trend in the estimated warning or background-color utilities during the course of the experiment.

$u_B(Gray)$. Thus, the positive sign of $u_B(Light\ Brown)$ means that the light brown color was perceived as *less risky* than the gray background color. The estimated utility parameters for the warnings and background colors were all different from zer ($p < 0.001$). The utility component for left-sided positioning on the computer screen was set to $u_M(Left) = 0$. The estimate $\hat{u}_M(Right) = 0{,}209$ (standard error 0.082) thus indicates that for the sample as a whole, there was a significant right-sided positioning effect.

In model 1, we could not reject the hypothesis that $u_W(Fetus) = u_W(Mouth)$. To economize on parameters, we therefore ran model 2 under the restriction that smokers were indifferent between the two warnings, that is, $u_W(Fetus)$ and $u_W(Mouth)$ shared a common value $u_W(Fetus\ or\ Mouth)$. This simplification did not significantly alter the estimated utility components. We tested an even more concise specification in model 3, where the light brown and gray background colors together served as the omitted category. In that model, $\hat{u}_B(Dark\ Brown)$ derived from model 3 was significantly different from the corresponding estimate derived from model 1 (p =0.004).

An additive utility function $u(x) = u(w, b) = u_W(w) + u_B(b)$ is also lexicographic when the minimum absolute difference between any two warning utilities exceeds the maximum absolute difference between any two background-color utilities [26]. Using the estimated values $\hat{u}_W$ and $\hat{u}_B$, we found that only model 3 demonstrated consistency with lexicographic utility for the entire sample of 97 smokers. We calculated the statistic $Q = \min abs_{w,w' \in W}\left(\hat{u}_W(w) - \hat{u}_W(w')\right) - \max abs_{b,b' \in B}\left(\hat{u}_B(b) - \hat{u}_B(b')\right)$ and then tested the one-sided null hypothesis that $Q < 0$. In model 3, the test rejected the null hypothesis that $Q < 0$ ($p < 0.001$).

Response Time

For all choice sets among all smokers, the mean response time (from the appearance of each choice set on the computer screen until the smoker clicked on the pack perceived as less risky) was 4.408 seconds, with a median of 2.78 seconds and a range of 0.19 to 52.8 seconds.

Among the 12 choice sets described in Table 1, three sets (B, G and H) compared packages with identical warnings, while the remaining nine sets compared packages

with distinct warnings. Figure 2 below shows the mean response time in relation to the sequential order of the choice set and the presence or absence of identical warnings. As Figure 2 shows, there was an overall downward trend in the mean response time during the course of the experimental task. Whether early or late in the overall sequence of choice sets, participants spent more time reaching a decision when faced with a comparison of packages with identical warnings. By contrast, the mean response time had no relation to the presence or absence of identical background colors.

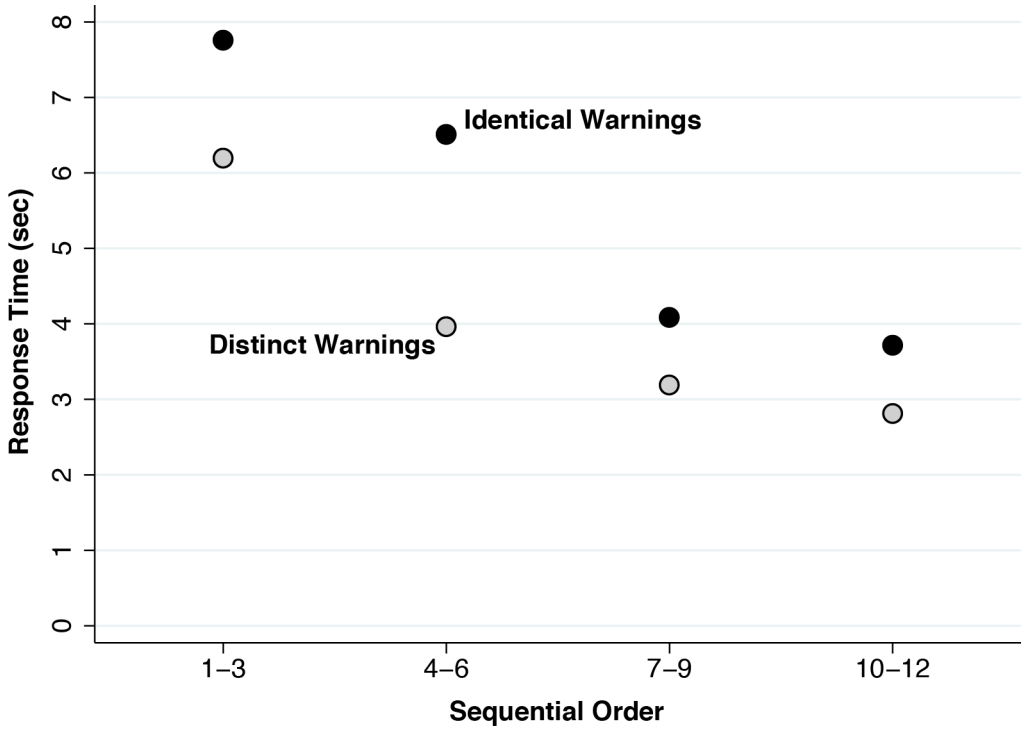

Figure 2. Mean response time in relation to sequential order and the presence or absence of identical package warnings in the choice set.

For each of the 12 binary choice sets $\{x, x'\}$ in each of the two groups our experiment, we used the parameter estimates in model 3 to compute the quantity $\Delta\hat{u} = |\hat{u}(x) - \hat{u}(x')|$ as a measure of the divergence in utility between the two package alternatives. Since the calculation included the estimated positioning effect $\hat{u}_M(Right)$, the estimated values of $\Delta\hat{u}$ for any given choice set differed between Groups I and II. When $\Delta\hat{u}$ is large, there is a strong preference for one of the alternatives, but when $\Delta\hat{u}$ is small, the choice between the two packs is a close call.

For each choice set and group, Figure 3 relates $\Delta\hat{u}$ to the mean response time. The figure confirms that response time is inversely related to the estimated difference in utility between the two package alternatives. The sets with the lowest values of $\Delta\hat{u}$ were B, G and H, precisely those in which the warnings were identical. The significant negative relation between the two variables was confirmed in a weighted least squares regression, where the weights were the estimated inverse standard errors of the mean response time (estimated slope = –0.723, $p = 0.001$). We also obtained a significant inverse relationship when we instead used models 1 and 2 to compute $\Delta\hat{u}$.

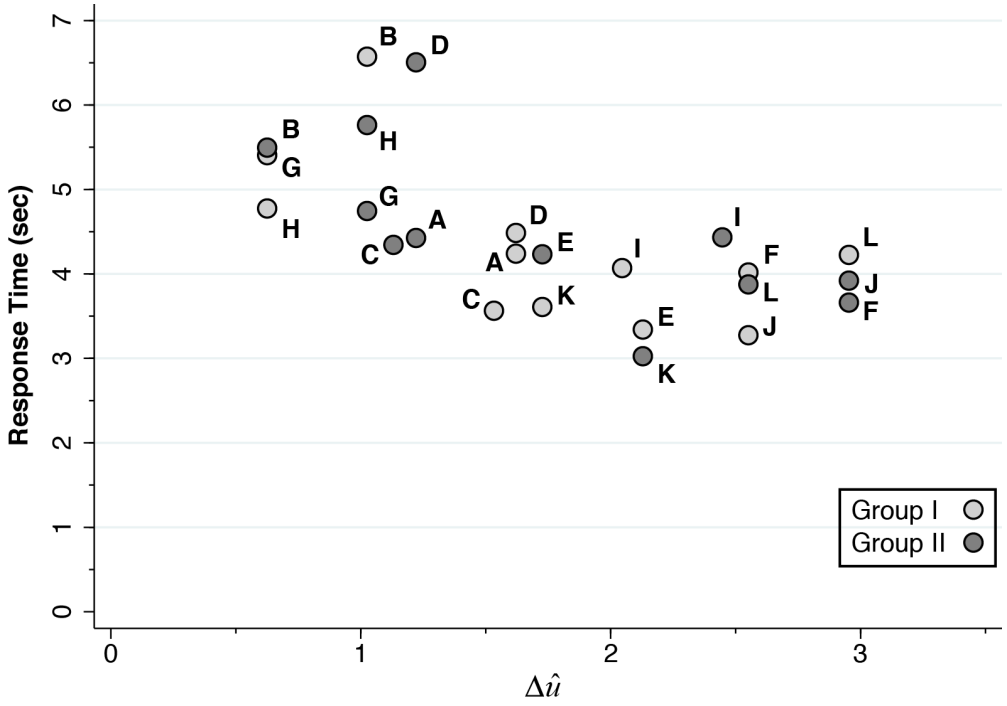

Figure 3. Relation between mean response time and estimated difference in utility among 12 choice sets in each of the two groups.

Eye Tracking

We studied the sequence of eye fixations in relation to the presence or absence of identical warnings in the choice set. In both cases, we found that in the vast majority of choice sets, participants first fixated on a package warning – in 85.9% of choice sets with identical warnings and in 84.3% of choice sets with distinct warnings. Among those choice sets where the participant first fixated on one of the package warnings, about two-thirds then fixated on the other package warning –

in 66.0% of choice sets with identical warnings and 67.5% of choice sets with distinct warnings. Tests for differences in proportions showed that the initial sequence of fixations was independent of the presence or absence of identical warnings in the choice set. For further details, see Appendix 2.

Figure 4 measures the mean number of fixations outside the two package warnings in relation to the sequence number of the choice set in the experimental task. Again, we distinguish between choice sets with and without identical package warnings. As Figure 4 shows, participants made substantially more fixations on areas outside the package warnings when they were confronted with choice sets with identical warnings. The excess number of fixations declined during the course of the experimental task. In a linear regression of the number of non-warning fixations as a function of the type of choice set and sequence number, with fixed effects for each participant, all of the main effects and interactions were significant ($p < 0.05$).

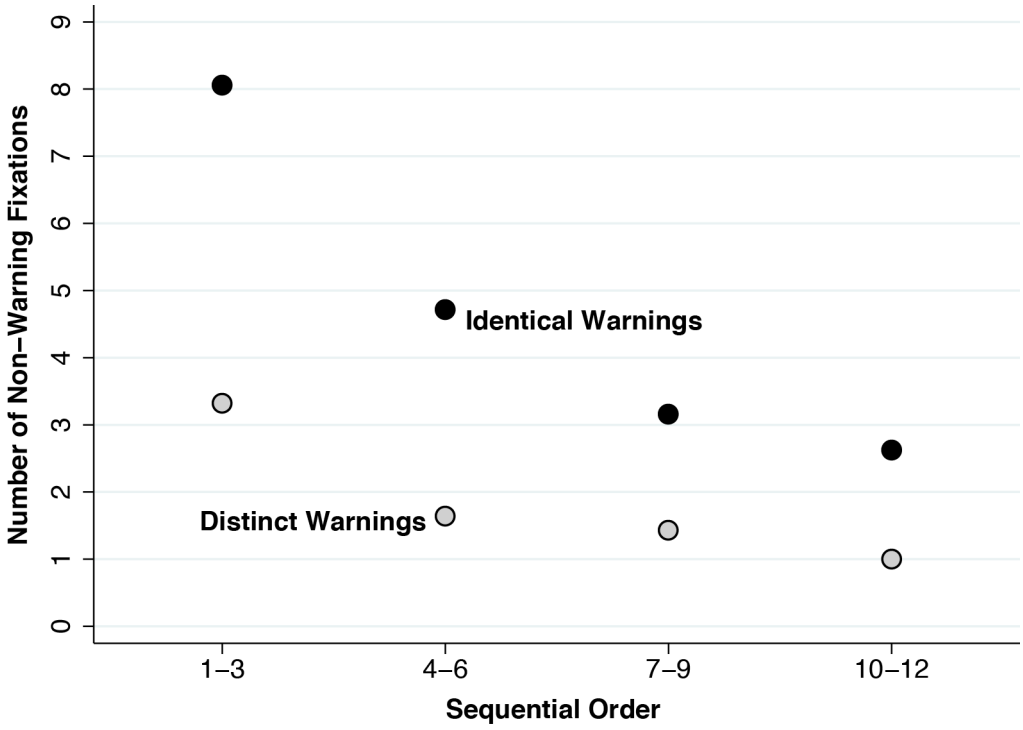

Figure 4. Mean number of fixations outside of package warnings in relation to sequential order and the presence or absence of identical package warnings in the choice set.

Violators versus Non-Violators

As summarized in Table 2, of the 97 participants in our experiment, 63 (64.9%) passed all six tests of additive or lexicographic utility, while 34 (35.1%) violated at

least one of the six conditions. Here, we term the latter group the "violators" and the former group the "non-violators," and report on differences between these two groups.

We found no significant differences between violators and non-violators in mean age, the proportion of females, the proportion of students, the proportion that attempted to quit in the past year, or the time to first cigarette. We did find, however, that violators smoked significantly fewer cigarettes per day than non-violators.

Addressing possible positioning effects, we found that the mean number of right-sided choices was 6.882 among the 34 violators, as compared to a mean of 6.000 among the 63 non-violators. Running the conditional logit models of Table 3 separately on the two groups showed significant coefficients for *Right Side* only among the violators. Addressing possible ordering effects, we measured the absolute distance between the first and last choice set in each of our six tests. The underlying logic was that the larger the distance, the more susceptible would participants be to learning or fatigue effects. Except for test 3, where the mean distance between sets A and I was 5.08 for violators and 6.75 for non-violators ($p = 0.093$), we found no significant differences between violators and non-violators.

Moreover, we found that violators had significantly longer response times and made significantly more eye fixations than non-violators. The mean response time was 5.470 seconds among the violators (standard error 0.329) and 3.848 seconds among the non-violators (standard error 0.137, $p < 0.001$). We found that this significant difference in response times persisted even when we took our measure of divergence in utility $\Delta\hat{u}$ into account. In a weighted linear regression of response time as a function of $\Delta\hat{u}$ and an indicator variable for violator status, the effect of the latter variable was a 1.655-second increase in response time ($p < 0.001$). The mean number of fixations per choice set was 20.363 among the violators and 12.447 among the non-violators ($p < 0.001$).Violators also spent more time on each fixation. Specifically, the mean duration per fixation was 178 ms among the violators and 169 ms among the non-violators ($p = 0.018$).

Finally, we found that violators were more likely than non-violators to describe the images of the fetus, cadaver and mouth tumor as aversive. Focusing specifically on

the descriptors “frightening,” “disgusting,” “horrible,” “severe,” “scary,” “difficult to look at,” and “astonishing,” we found the mean number of mentions of these descriptors was 0.941 per violator, compared to 0.571 per non-violator ($p = 0.043$). These results are similar to what emerged in previous studies by Moog et al. (2005), who found longer fixation times for smoking-related cues in individuals with lower levels of nicotine dependence.

5. Discussion

Main Findings and Limitations

In a discrete choice experiment, we asked 97 cigarette smokers to choose the less risky alternative among 12 pairs of cigarette packages with varying warnings and background colors. Participants described the warnings as disgusting and frightening, and some had trouble even viewing them. Nonetheless, nearly all made choices that satisfied the axioms of rational choice, including context independence and transitivity. What’s more, 65 percent of participants made choices that satisfied six separate tests for the presence of additive or lexicographic utility. These smokers used the package warnings to decide which cigarette was less risky and relied on background colors only to break ties.

To shed light on the cognitive processes underlying the participants’ choices, we focused on their differential responses to two types of binary choice sets – those in which both cigarette packs had identical warnings and those in which each pack had a distinct warning. We found that smokers spent significantly more time making a decision in the former case than in the latter. Utilizing the technique of eye tracking, we found that smokers initially approached both types of choice set in the same manner. They first fixed their gaze on the warnings on each of the two cigarette packs. Thereafter, their gaze patterns diverged. We observed significantly more fixations on non-warning elements of each cigarette package when the two packages had identical warnings. The observed sequence of eye fixations was consistent with a lexicographic choice strategy.

We further studied the 35 percent of participants who did not pass all six tests for additive or lexicographic preferences. These smokers were significantly more likely to describe the warnings as threatening, repugnant, and difficult to look at. They

had significantly longer response times and more eye fixations. They also had a significant preference for choosing packs on the right side of the computer screen. Less able to tolerate the aversive content of the images, they made noisier decisions, often tending simply to click on the package at the right.

By contrast, the 65 percent of participants passing all six tests, who smoked more cigarettes per day, were better capable of blocking out these aversive stimuli and thus making less noisy decisions. Their addiction suppressed the objective evaluation of the images and replaced it with a depersonalized construct that permitted them to engage in what economists and other social scientists have characterized as rational choice.

We asked participants which cigarette package was less risky for their health. We chose this endpoint to avoid the complexities of interpretation inherent in intent to purchase, which would entail the additional intervening factor of price. A focus on endpoints other than intent to purchase has become increasingly common in discrete choice experiments (Clark et al., 2014; Soekhai et al., 2019). Avoidance of monetary outcomes may also reduce the likelihood of preference reversals (Alós-Ferrer et al., 2021).

When it comes to risk perception, we found significant evidence of lexicographic preferences over two attributes: package warnings and background color. We did not establish that cigarette smokers generally use lexicographic heuristics to evaluate other cigarette pack attributes.

Relation to Earlier Work and Directions for Future Research

We are hardly the first investigators to find that decision-makers use lexicographic strategies to simplify the choice among alternatives with multiple attributes (Colman & Stirk, 1999; Dhami & Mandel, 2013; Dieckmann et al., 2009; Rosenberger et al., 2003; Slovic, 1975; Tversky & Sattah, 1979; Tversky et al., 1988; van de Kaa, 2017; Yee et al., 2007).

Nor are we the first to use the technique of eye tracking in the field of tobacco research. Others have used the technique to study which portions of the cigarette package individuals tend to focus on or avoid (Kessels & Ruiter, 2012; Krugman et al., 1994; Maynard et al., 2014; Meernik et al., 2016; Munafo et al., 2011;

Shankleman et al., 2015; Strasser et al., 2012). Our study used the sequence of eye fixations – rather than simply the total number and duration – to elucidate information on search patterns (Russo & Rosen, 1975).

Our finding that response time and the number of eye fixations declined with successive computer screens is generally consistent with other eye-tracking studies. The two principal explanations for this phenomenon are learning and fatigue (Campbell et al., 2015; Czajkowsk et al., 2014; Day et al., 2012). Our finding that response time is inversely related to the absolute difference in utility between the two alternatives is consistent with the drift diffusion model (DDM), a satisficing theory of choice that emphasizes the costs and benefits of acquiring additional information during the decision-making process (Krajbich et al., 2014).

Studies utilizing eye tracking during a discrete choice experiment have not always found a strong relation between fixations and preferences (Balcombe et al., 2017). Researchers have recognized the difficulty of identifying the causal relations between fixation and choice solely from the data on the joint distribution of these two endogenous variables (Krucien et al., 2017; Shimojo et al., 2003). In top-down control of visual attention, preferences determine eye movements. In our context, the smoker tends to look at the cigarette package he/she eventually chooses. Under bottom-up control, by contrast, fixations drive preferences (Alós-Ferrer et al., 2021). Repeatedly looking at the warning enhances the probability that the pack will be chosen (Orquin & Mueller Loose, 2013). Future research will require new instruments to distinguish between these two causal pathways.

While studies of risk-taking and time preference among cigarette smokers are abundant (Chao et al., 2015; Hardisty et al., 2013; Szrek et al., 2012), we are unaware of specific studies of rationality and decision-making heuristics among smokers, especially in relation to measures of degree of addiction or intensity of smoking. Uruguay, a country in South America with about 3 million inhabitants, instituted a nationwide anti-smoking campaign in 2005 (Abascal et al., 2012; Triunfo et al., 2016). During the campaign, the proportion of pregnant women who were smoking at the start of their pregnancy dropped significantly, while the proportion of pregnant smokers who had subsequently quit by the third trimester of pregnancy increased from about 15 to 43 percent. Yet among those women who

quit during pregnancy and got pregnant again, nearly half had resumed smoking by the start of the subsequent pregnancy (Harris et al., 2015). Understanding how addiction influences rational choice is critical to designing public policies to reduce the burden of tobacco use.

6. Conclusions and Policy Recommendations

Our findings demonstrate that smokers, despite being exposed to repugnant and aversive warnings, make decisions consistent with rational choice models, often using lexicographic strategies to prioritize warnings over other attributes such as background color. This underscores the potential of cigarette packaging as a tool for influencing risk perceptions. However, it also highlights the limits of such interventions, as addiction enables smokers to suppress emotional responses, diminishing the deterrent impact of aversive stimuli.

These results align with the objectives of plain packaging as outlined by the World Health Organization (WHO). Plain packaging is defined as measures to restrict or prohibit the use of logos, colors, and promotional information on tobacco packaging, allowing only standardized text in a uniform color and font. Its goals include reducing the attractiveness of tobacco products, eliminating packaging as a form of advertising, and enhancing the visibility of health warnings. The evidence from our study supports the continued implementation and strengthening of plain packaging policies as part of a comprehensive approach to tobacco control (WHO, 2022).

Our findings suggest several policy recommendations. First, to counteract the desensitization observed among smokers, health warnings should be updated frequently and designed to maximize emotional salience. This could include the use of dynamic or rotating images, as recommended by the WHO. Second, background colors, which influence risk perception, should be standardized to universally unattractive tones, such as Pantone 448C, already mandated in several countries. Third, policymakers should consider expanding plain packaging regulations to include emerging tobacco products, ensuring consistency across all product categories.

Additionally, the cognitive mechanisms observed in our study highlight the importance of integrating packaging policies with broader tobacco control strategies. Public awareness campaigns, behavioral interventions, and support systems targeting individuals with higher levels of addiction can complement the effects of packaging regulations. Such integrated efforts align with the WHO's recommendation that plain packaging should form part of a holistic tobacco control framework, which includes restrictions on advertising, promotion, and sponsorship, as well as the implementation of large graphic health warnings.

Finally, our findings underscore the need for ongoing evaluation of plain packaging policies. Studies should focus on how these measures influence different demographic groups and smoking behaviors over time, allowing for adaptive policy responses. By addressing both the cognitive and behavioral dimensions of smoking, a comprehensive strategy that includes plain packaging can significantly reduce the global burden of tobacco use.

Prior Publication

A preliminary version of this manuscript was first posted as a working paper on the National Bureau of Economic Research website (Harris, Gerstenblüth and Triunfo 2018). A revised version of posted on the medRxiv preprint server (Gerstenblüth, Harris and Triunfo 2022).

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Ethics approval

This study was approved by the Ethics Committee of the School of Chemistry of the Universidad de la República, Uruguay.

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Appendices

Appendix 1. Descriptive statistics of participants

Table 1A. Descriptive Statistics for 97 study participants

	Mean	SD
Female (%)	59.8	
Age (years)	28.2	8.8
Education attained:		
Some high school (%)	1.0	
Completed high school (%)	1.0	
Technical education (%)	6.2	
Some university (%)	75.3	
Graduated university (%)	8.3	
Graduate study (%)	8.3	
Cigarettes smoked per day:		
1–10 (%)	44.3	
11–20 (%)	40.2	
21–30 (%)	10.3	
More than 30 (%)	5.2	
Time to first cigarette on arising in a.m.:		
0–5 min. (%)	12.4	
6–30 min (%)	39.2	
31–60 min. (%)	18.6	
More than 60 min. (%)	40.2	
No response (%)	2.1	
Tried seriously to quit during past year (%)	28.9	
Believes that smoking causes lung cancer (%)	93.8	
Believes that smoking causes heart disease (%)	90.7	
Believes that smoking causes syphilis (%)	14.4	

*Includes 97 of 98 recruited subjects who completed the entire experiment. All participants were self-reported current cigarette smokers.

Appendix 2. Details of Eye Tracking Methodology

Each participant was asked to sit at a distance of 65 cm in front of a 17-inch, 1280x1024-pixel LCD monitor of a Tobii T60 eye tracker (Tobii Technology, 2011). While seated in front of the eye tracker, but before starting the task, participants underwent a standard calibration procedure (Tobii AB, 2016). Immediately before the appearance of each of the 12 choice sets, the computer monitor showed only a fixation cross, centered on the screen, for 0.2 seconds. That way, participants were induced to fix their gaze at a predetermined point before looking at any details of the two packs in the choice set that was to appear next.

During the task, the eye tracker noninvasively recorded participants' eye movements at a sampling frequency of 60 Hz. The accompanying software (Tobii AB, 2016) classified participants' eye movements into two types: *fixations* and *saccades*. A fixation corresponds to a state where the eye remains relatively still over a period of time, while a saccade corresponds to the rapid motion of the eye from one fixation to another. The classification is based on the velocity of the directional shifts of the eye (Salvucci & Goldberg, 2000). If the velocity is higher than 30 visual degrees per second, the eye movement is classified as a saccade. If the velocity is below this threshold, the eye movement is classified as part of a continuing fixation.

We further classified the participants' fixations according to their corresponding coordinates on the computer screen. In accordance with recommended practice (Holmqvist et al., 2011), we partitioned the screen coordinates into five mutually exclusive *areas of interest*, specifically, the warning image, the warning text, the lateral text, the toxic-product symbol, and the brand name.

To illustrate the data acquisition process, Figure A1 below shows the eye fixations of participant 30 on choice set J, which appeared next to last in her 12-set task. Superimposed on the two-pack choice set is the standard representation for fixations and saccades (Salvucci & Goldberg, 2000), where each fixation is a circle with diameter proportional to its duration, and where a connecting line represents a saccade.

Participant 30's first fixation, lasting 180 milliseconds (ms), was on the image in the boot warning on the left. After a 50-ms saccade, her second fixation, lasting

580 ms, was on the image of the mouth warning at the right. Shown below the two packs is a time line of her eye movements, where each minor tick represents 100 ms. Her first fixation occurred 280 ms after choice set J appeared on the computer screen. Her second fixation occurred 510 ms into the task. At 1090 ms, the participant clicked her mouse, choosing the pack on the left as less risky, thus ending the task. In this choice set, which was introduced near the end of the experimental task, the participant fixated only once on each of two areas of interest on the computer screen and then made her choice. In other cases, participants fixated repeatedly on the same or different areas of interest, going back and forth between the two packs, before making a decision.

Figure A1. Eye fixations by participant 30 on choice set J

Appendix 3. Details of Eye Tracking Search Patterns

Figure A2 shows the initial fixation patterns of the 97 participants in relation to the presence or absence of identical warnings in the choice set. The figure shows two decision trees. The tree at the left corresponds to $3 \times 97 = 291$ choice sets with identical warnings, while the tree at the right corresponds to $9 \times 97 = 873$ choice sets with distinct warnings. These numbers appear inside the decision nodes at the root of each tree.

Along the branches emanating from the decision node at the root of each tree, we show the proportions of choice sets in which participants did or did not initially fixate on a package warning, including the image or text. Thus, proceeding along the upper branch labeled "Fixate on Warning" in the tree on the left, we see that participants fixated initially on a warning in 250 (85.9%) of the 291 choice sets with identical warnings. In the tree on the right, proceeding along the corresponding branch labeled "Fixate on Warning," participants fixated initially on a warning in 736 (84.3%) of 873 choice sets with distinct warnings. There was no significant difference between the two types of choice sets – identical versus distinct warnings – in the probability of initially fixating on a package warning.[8]

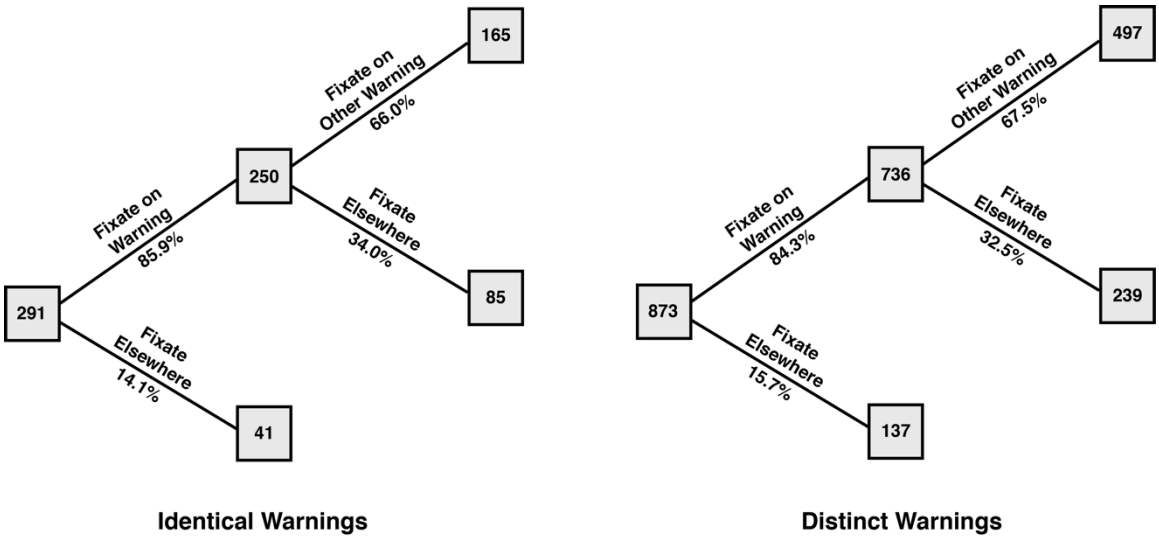

Figure A2. Initial fixation patterns in relation to the presence or absence of identical package warnings in the choice set.

Proceeding along the branch labeled "Fixate on Warning" emanating from the root of each tree, we arrive at another decision node. The number of choice sets in which participants initially fixated on a warning (250 and 736, respectively) is shown inside each node. From that node, we determine the proportion of choice sets in

[8] In a linear regression of initial fixation on a package warning as a function of the type of choice set and the sequence number, with fixed effects for each individual, the coefficient of the identical-warning type was 1.72% with $p = 0.417$.

which participants then fixated on the other package warning. While they may have fixated back and forth on the text and image of the first warning, the other warning had to be the next distinct area of interest to receive a fixation. In the tree at the left, we find that participants next fixated on the other package warning in 165 (66.0%) of 250 choice sets. In the tree at the right, the proportion was 497 (67.5%) of 736 choice sets. Thus, there was no significant difference between the two types of choice sets in the conditional probability of fixating on the other package warning, given that a participant had initially fixated on one package warning ($p = 0.933$).

Top-Down versus Bottom-Up Processing of Cigarette Package Warnings: Experimental Evidence from Uruguay

Mariana Gerstenblüth[9]

Abstract

This study explores the interplay between bottom-up and top-down mechanisms in decision-making, particularly in the context of cigarette package warnings designed to reduce smoking prevalence. Using experimental methods, we examine how visual salience, addiction, and package attributes influence attention and choice behavior. Results show that younger participants, who are less addicted, are more influenced by salience cues, such as the order in which packages are presented. In contrast, older, more addicted individuals rely predominantly on top-down control mechanisms, guided by pre-existing preferences and cognitive evaluations.

Our findings highlight that the effectiveness of health warnings varies across demographic and addiction profiles, with younger individuals being more responsive to salient designs. This distinction underscores the importance of tailoring regulatory strategies to different smoker groups, particularly focusing on those in the early stages of addiction. Moreover, while top-down processes dominate in more entrenched smokers, the strategic use of bottom-up cues could enhance the impact of health warnings among less dependent populations. These insights provide valuable guidance for policymakers in designing interventions that effectively discourage smoking and promote healthier choices.

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Key Words: addiction, health warnings, top-down, bottom-up, attention, eye tracking, tobacco

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1. Introduction

Understanding whether attention or preferences drive decision-making is crucial for informing regulatory strategies concerning health-related warning labels, especially in the context of addictive products such as tobacco. Attention can be influenced by top-down and bottom-up processes, which shape individuals' responses to stimuli. According to Wolfe (2021), attention is directed by a dynamic interplay between multiple sources of guidance, including top-down and bottom-up processes, which combine to form a "priority map" that determines where attention is allocated. Top-down processing refers to how pre-existing knowledge, expectations, and goals influence attention. If preferences determine attention, individuals have already made their decisions based on prior preferences and beliefs before exposure to the stimuli. By contrast, bottom-up processing refers to how external stimuli influence attention. If attention drives preferences, the visual saliency of warning labels can play a significant role in capturing attention and shaping preferences. Understanding this interplay is essential, as it can guide policymakers in developing more effective interventions to discourage harmful product consumption by designing warning labels that effectively capture attention and influence decision-making.

Uruguay provides a valuable case study for examining the impact of regulatory policies on the consumption of harmful products. Following its ratification of the Framework Convention on Tobacco Control in 2004, the country has implemented stringent measures, including plain packaging, advertising restrictions, smoking cessation programs, and significant tax increases on tobacco. These policies have resulted in substantial reductions in smoking prevalence, both among adults (33% between 2006 and 2022) and adolescents (72% between 2003 and 2021). Additionally, the average age of smoking initiation has increased from 13 to 14.4 years. These achievements not only highlight the effectiveness of regulatory interventions but also underscore the importance of understanding how visual design and health warnings on packaging influence consumer preferences and decision-making (Gerstenblüth & Triunfo, 2024).

This study employs a discrete choice experiment supplemented by the well-established technique of eye tracking to disentangle the link between fixations and preferences. Eye tracking enables us to examine individuals' visual attention by precisely measuring their eye movements and fixations. By studying where individuals look and for how long, it is possible to gain insights into the attentional processes underlying decision-making. Using Sims' (2003) rational inattention theory and Bordalo et al.'s (2012) salience model, we explore how smokers process visual information in a context where attention is a limited resource, especially in health-related decision-making. Prior literature has explored these concepts, but identifying the causal relationship between fixation and choice has remained challenging due to the endogenous nature of the variables (Balcombe et al., 2017; Krucien, Ryan, & Hermens, 2017; Shimojo et al., 2003).

In this paper, we present the results of an experiment specifically designed to address the causal relation between fixation and choice by exogenously influencing fixations to observe their effect on preferences. Our approach aims to determine whether preferences guide eye movements or if visual attention shapes preferences. If preferences determine eye movements, people will choose first and then fix their gaze on the preferred option. Alternatively, if fixations drive preferences, increased attention to a stimulus will enhance the probability of choosing it (Alós-Ferrer et al., 2021). Our experiment allows us to explore whether pre-existing preferences guide attention toward specific elements of cigarette packaging (top-down process), or if visual attention to salient warnings can influence preferences (bottom-up process).

Our research contributes to the existing literature in several key aspects. Firstly, we delve into a pivotal area of decision-making, exploring the dynamics of top-down and bottom-up control within the context of tobacco addiction. Secondly, we employ a novel approach to disentangle the attention endogeneity problem by implementing a meticulously designed eye-tracking experimental task, which rigorously examines the role of visual saliency in health warnings. Consequently, our study sheds light on the effectiveness of regulatory measures and health policies focused on labeling harmful products, with a particular emphasis on cigarettes. This

research not only enhances the understanding of decision-making processes in addiction but also provides valuable insights for policymakers and health advocates.

2. Attention and Decision Making under Addiction

Economists and psychologists have long recognized that attention is a scarce resource and, consequently, the acquisition of information relevant to decision-making is a costly process (Stigler, 1961). As Herbert Simon (1971) aptly observed, "A wealth of information creates a poverty of attention. That leads us to inquire: What strategies do decision makers use to allocate their scarce attention to process information? What information, among an abundance of available data, impacts their choices?

An ample body of research demonstrates that decision makers intentionally disregard a substantial portion of the available information during the decision-making process (Orquin et al., 2018). While the discarding of less relevant information might be considered rational, we need to recognize that biases in visual perception can distort the decision-making process. As a result, the visual presentation formats can lead decision makers to attend to or overlook specific information, ultimately influencing their choices (Orquin et al., 2018). The extent to which visual presentation may bias the acquisition of relevant information depends on the balance between bottom-up and top-down control of attention.

Top-down control refers to the influence of higher-level cognitive processes, such as goals, expectations, and prior knowledge, on attentional allocation and decision making. It involves the deliberate direction of attention towards specific stimuli or features based on internal goals or cognitive biases. It can also be viewed as a manifestation of the rational inattention economic model introduced by Sims (2003), capturing the way decision makers optimally allocate their attention, focusing on attributes that are most likely to influence their choices.

On the other hand, bottom-up control of attention refers to the automatic and involuntary process by which attention is captured by salient external stimuli. It involves processing information without being heavily influenced by pre-existing knowledge or expectations. It allows individuals to be responsive to salient features.

According to Wolfe (2021) model, bottom-up salience is another key contributor to the priority map, representing stimulus-driven guidance that can capture attention even against the observer's intentions. From an economics perspective, it is represented in the decision-making model proposed by Bordalo et al. (2012, 2013), which introduces the concept of salience as a measure of the ease with which different choice attributes are noticed by the decision maker. Attributes with higher salience are assigned greater weight in the decision-making process. Importantly, the salience operates mechanically, without explicit optimization by the decision maker, which can lead to behavioral biases.

Addiction significantly influences the allocation of attention through reinforcing top-down control mechanisms. Several mechanisms contribute to this phenomenon, including cognitive biases and denial, immediate gratification from nicotine cravings overpowering long-term health concerns, and impaired self-control hindering behavior change. Addiction may strengthen certain top-down priorities, making it more challenging for bottom-up salience alone to redirect attention toward health warnings. Moreover, addiction often involves previous rewards that reinforce the idea of top-down control. Impairment in this control is evident among substance abusers, as they may struggle to deliberately control or suppress automatic behaviors (Billieux et al., 2010; Groman, James, & Jentsch, 2009).

However, it is possible to expect different behavior in the case of different levels of addiction. In the case of tobacco, smokers with higher levels of dependence are more likely to develop habitual smoking behavior, contributing to impulsive decision making (Field & Cox, 2008) and a goal-driven attentional bias (Brown et al., 2018), whereas non-dependent smokers may be more salience-driven (Wilkinson, 2021).

Health warnings are effective if perceptual salience can induce bottom-up effects of overt selection. Previous eye-tracking experiments showed that plain packaging can increase visual attention to health warnings in adult (Munafò et al., 2011) and adolescent (Maynard et al., 2013) non-smokers and non-regular smokers. By enhancing the visual salience of health warnings, policymakers can leverage bottom-up attention mechanisms to capture the focus of consumers, potentially overriding habitual top-down biases associated with addiction.

In the context of addiction, individuals' behaviors can be considered rational from a top-down perspective. However, the goal is not to perpetuate this rationality but to implement nudges that direct attention towards the salience of health warnings on packages. The focus is on forcing attention towards warning messages that contradict current goals of substance use. By forcing the producers of addictive products to place salient information on their packages, there is a greater chance that consumers will notice such information (Graham, Orquin, & Visschers, 2012). However, such regulations may prescribe changes that are too small to actually make a difference if attention is driven predominantly by top-down control.

3. Methodology

Experimental Design

The experiment described in Harris, Gerstenblüth and Triunfo (2018) is modified to assess the effect of biasing subject's initial attention. In our prior experiment, subjects were shown a centered fixation cross before each stimulus screen. Each stimulus screen simultaneous displayed two cigarette packs, from which the subject had to select the least risky one. In this alternative experiment, following Tavares et al. (2017), the subject is first shown a screen with only one of the two cigarette packs. After a predetermined delay of 2.5 seconds, determined from a pilot trial, the subject was then shown the second pack and asked to choose between them (see figure 1). As fixations are correlated with attention, it was important that the image was available for at least 0.2 seconds, that is, the minimum time needed for the eyes to stabilize in the fovea. As in our prior experiment, we adopt a forced-choice design with twelve choice sets shown on the computer monitor. We randomize the sequential order and the right-left orientation for each choice set, and the image that is made salient within each set.

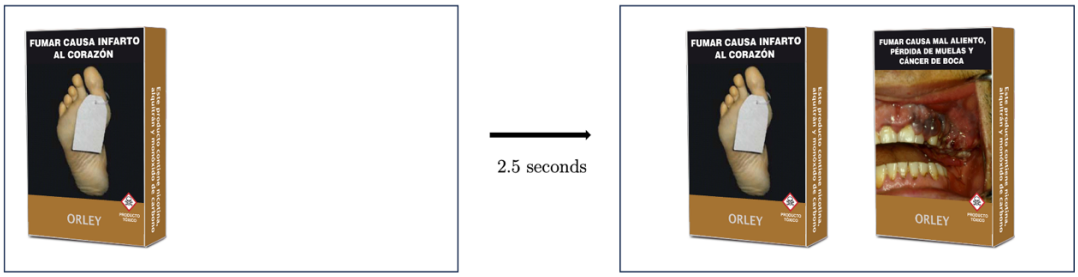

Figure 1. Example of the display of a single warning on the left, followed by presentation of the two-package choice set after a delay of 2.5 seconds.

The experimental cigarette packages had varying warnings as well as varying background colors. To avoid familiarity that could reduce attention, neither the specific warnings nor the brand corresponded to real-marketed products. Warnings contained three different images, all of which were repulsive and threatening: cadaver with a tag (*Cadaver*), fetus in a hand (*Fetus*), and a mouth tumor (*Mouth*). There were three different background-colors: *Grey*, *Light Brown*, and *Dark Brown.* The latter color corresponded to the plain packaging now in force in many countries (see figure 2).

Figure 2. Examples of experimental packages with the three warnings (cadaver, fetus and tumor) with respective background colors grey, dark brown, and light brown.

Throughout the experiment, a Tobii T60 eye tracker noninvasively recorded participants' eye movements[10].

[10] The use of eye tracking in this experiment does not aim to analyze traditional metrics such as fixations or visual trajectories. Instead, it is employed solely to ensure that participants first view a specific package, maximizing its salience within the experimental design.

Participants

In this study, 100 self-reported adult current cigarette smokers aged 18-66 years were recruited from the students, faculty, and staff of the Universidad de la República in Montevideo, Uruguay. Table 1 presents the descriptive statistics of the 100 participants who completed the entire experiment. The sample consisted of 51% females and 49% males, with a median age of 31.4 years. We also calculated a two-component version of the Fagerström test (Heatherton et al. 1991), to assess nicotine dependence levels of our participants.

All study participants reported normal or corrected-to-normal vision as well as full-color vision. Participants gave written informed consent and received a gift for participating in the study. The Ethics Committee of the School of Psychology of the Universidad de la República, Uruguay, approved our study protocol.

Table 1. Descriptive statistics for 100 study participants.

Variable	Mean	SD
Female (%)	51.0	
Age (years)	31.4	10.5
Cigarettes smoked per day:		
1–10 (%)	64.0	
11–20 (%)	30.0	
21–30 (%)	5.0	
More than 30 (%)	1.0	
Time to first cigarette on arising in		
0–5 min. (%)	2.0	
6–30 min (%)	10.0	
31–60 min. (%)	26.0	
More than 60 min. (%)	62.0	
Tried seriously to quit during past year (%)	46.0	
Fagerström Test:		
Low dependence (%)	67.0	
Medium dependence (%)	32.0	
High dependence (%)	1.0	

Estimation Strategy

Conditional Logit Estimates of First Package

Central to the conditional logit model is the notion that individuals base their choices on a utility-maximizing framework. In this framework, each alternative is associated with a utility value, based on both observable attributes (such as the components of the health warnings) and latent factors (individual-specific tastes and unobservable attributes). Conditional logit models serve as a fundamental analytical tool for understanding the dynamics of discrete choice scenarios, wherein individuals are confronted with a set of mutually exclusive alternatives and are tasked with selecting one among them. This modeling approach finds particular relevance in our context, where individuals had to choose the package that they considered less risky for their health.

The utility derived from each package can be expressed as follows:

$$U_{ij} = u_w(w_{ij}) + u_B(b_{ij}) + u_R(r_{ij}) + u_{FP}(fp_{ij}) + \varepsilon_{ij} \quad (1)$$

In this specification, U_{ij} represents the utility of package j for individual i. The term $u_W(w_{ij})$ captures the utility derived from the warning image on the package, while $U_{ij} = u_B(b_{ij})$ represents the utility associated with the package's background color. Additionally, $u_R(r_{ij})$ reflects a systematic preference for packages appearing on the right side of the screen, which may indicate spatial biases in attention allocation. A significant coefficient for this term would suggest that participants defaulted to spatial heuristics, indicating diminished engagement with the experimental task. Finally, $u_{FP}(fp_{ij})$ captures the utility derived from the first package in the choice set, reflecting the salience effect introduced in the experimental design.

Testing the role of *bottom-up* control involves assessing whether $u_{FP}(fp_{ij}) \neq 0$. A significant coefficient for $u_{FP}(fp_{ij})$ would indicate that the artificially salient package influences decision-making via *bottom-up* mechanisms. Conversely, a non-significant coefficient would suggest that participants rely more heavily on

top-down processes, focusing on the substantive attributes of the packages rather than their order of presentation.

Conditional Logit Estimates of Attribute Interactions

This model extends the utility framework described earlier by incorporating interaction terms between package attributes and their order of presentation in the experimental task. The objective is to investigate whether the salience of the first package influences individuals' choices differently depending on the specific attributes of the package, such as its image and background color.

The parameter estimates are consistent with an additive utility model, as outlined in equation 2:

$$U_{ij} = u_w(w_{ij}) + u_B(b_{ij}) + u_{FP}(fp_{ij}) + u_{WFP}(w_{ij} \times fp_{ij}) + u_{BFP}(b_{ij} \times fp_{ij}) + \varepsilon_{ij} \quad (2)$$

The interaction terms between the image and the order of presentation $u_{WFP}(w_{ij} \times fp_{ij})$, as well as between the color and the order of presentation $u_{BFP}(b_{ij} \times fp_{ij})$ are central to understanding the interplay between *bottom-up* and *top-down* processes in decision-making. The order of presentation, specifically whether a package appears first, reflects a *bottom-up* cue designed to manipulate salience by drawing participants' attention to that option. Significant interaction terms suggest that this salience effect is not uniform but instead depends on the specific visual attributes of the package, such as its image or color. This indicates that participants may rely more heavily on *bottom-up* cues when those attributes are particularly attention-grabbing or emotionally charged.

Conversely, if the interaction terms are not significant, it implies that participants are relying on *top-down* control, processing the visual attributes independently of their order of presentation and focusing instead on the substantive content of the packages to make their choices. The model thus enables us to test whether the decision-making process is primarily guided by automatic, externally driven (*bottom-up*) mechanisms or by deliberate, internally regulated (*top-down*) evaluation of the health warning attributes.

Conditional Logit Estimates considering Addiction-Driven Control

$$U_{ij} = u_w(w_{ij}) + u_B(b_{ij}) + u_{FP}(fp_{ij}) + u_{AGEFP}(age_i \times fp_{ij}) + \varepsilon_{ij} \qquad (3)$$

The model presented in equation (3) builds on the earlier specifications by incorporating the variable of age, which acts as a proxy for nicotine addiction. The inclusion of age is based on evidence that tobacco addiction is acquired and reinforced over time, typically starting during adolescence and continuing into the mid-to-late twenties. As individuals progress through the stages of addiction—from experimenting with cigarettes to developing full nicotine dependence—their behavior increasingly reflects the influence of *top-down* control mechanisms.

In this context, age captures an evolving balance between *bottom-up* and *top-down* processes in decision-making. Younger individuals, who are in the early stages of addiction with a relatively low "stock of addictive capital," are more susceptible to external salience cues such as the order of presentation or visual attributes of the package. Their decisions are more likely to be driven by automatic, *bottom-up* processes that respond to these cues. Conversely, as individuals age and their addiction becomes more entrenched, their actions are increasingly regulated by *top-down* mechanisms. These mechanisms reflect internalized habits and deliberate cognitive processes that diminish the influence of external salience cues on their choices.

The Fagerström test, while commonly used to measure nicotine dependence, was not employed in this study for two primary reasons. First, as described in the participant profile, the sample predominantly consists of individuals with relatively low levels of nicotine addiction, which limits the sensitivity and applicability of this measure in capturing meaningful variation in dependence. Second, the use of the Fagerström test in Uruguay could be controversial, given that the measure has not been validated for this population. These considerations make age a more suitable proxy for addiction in the present context, allowing for an analysis consistent with the theoretical framework and the characteristics of the sample.

Testing the interaction term $u_{AGEFP}(age_i \times fp_{ij})$ enables us to evaluate whether age modulates the effect of salience on decision-making. A significant negative coefficient for this term would suggest that older individuals are less influenced by the salience of the first package, providing evidence for the growing dominance of *top-down* control mechanisms as addiction deepens.

Ordinary Least Squares: Time to Click

In this analysis, we model the logarithm of the time individuals spend before making a decision, which reflects the cognitive effort or difficulty involved in the choice process. If attention is predominantly driven by bottom-up mechanisms, the presence of a salient first package is expected to reduce decision-making time, as it quickly captures attention and simplifies the choice. Conversely, if top-down processes dominate, decision times may be longer, as individuals deliberate based on pre-existing preferences, goals, or cognitive biases.

The predictors in this model include a variable indicating whether the first package was chosen, age (used as a proxy for addiction), and the set order in which choice tasks were presented. Age allows us to explore how addiction-driven differences in decision-making mechanisms influence cognitive effort, with younger participants potentially relying more on bottom-up salience cues and older participants engaging in more deliberate, top-down processing. The set order captures learning or fatigue effects as participants progress through the experiment. For instance, shorter decision times in later tasks could indicate greater familiarity with the experimental design or the adoption of simplified decision-making strategies (Campbell et al., 2015; Czajkowski et al., 2014; Day et al., 2012).

The interaction between bottom-up and top-down processes is particularly relevant when examining decision times. Quick decisions are often a result of alignment between salient external stimuli and pre-existing preferences, minimizing cognitive conflict. In contrast, when these processes conflict—such as when a visually salient package contradicts an individual's prior beliefs or preferences—decision times may increase as the individual resolves this discrepancy. This aligns with theoretical frameworks suggesting that attention allocation reflects a balance between automatic, stimulus-driven mechanisms and deliberate, goal-oriented processes.

Unlike standard discrete choice models, this analysis incorporates decision time as an outcome variable, leveraging eye-tracking data to examine the temporal aspects of decision-making. This approach reveals how bottom-up salience and top-down deliberation interact dynamically, influencing not only the choice itself but also the time required to reach that choice. For example, decision times can serve as a proxy for the level of cognitive effort required to process conflicting information or resolve attentional competition between stimuli. The inclusion of decision times complements the discrete-choice framework by providing richer insights into how attentional processes influence behavior, capturing both the ease of salience-driven decisions and the complexity of deliberative, top-down processing.

4. Results

Table 2. Conditional Logit Regressions estimates

Independent variable	Model 1	Model 2	Model 3
Fetus	1.716***	–0.081	1.728***
	(0.146)	(0.831)	(0.146)
Cadaver	2.976***	1.914**	2.998***
	(0.178)	(0.754)	(0.179)
Light Brown	-0.580***	0.704	-0.585***
	(0.183)	(0.701)	(0.183)
Dark Brown	-1.187***	–1.519**	–1.197***
	(0.197)	(0.735)	(0.197)
First Package	-0.037	-4,324***	
	(0.140)	(0.170)	
Right Side	0.037	0.083	
	(0.078)	(0.091)	
First Package*Fetus		4,255*	
		(1.700)	
First Package*Cadaver		4.610**	
		(1.653)	
First Package*Light Brown		0.568	
		(0.458)	
First Package*Dark Brown		4.278***	
		(0.975)	
First Package*Age			-0.202*
			(0,008)
All models had 2380 observations on 100 participants. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$. Clustered tandard errors are reported in parentheses			

Conditional Logit Estimates of First Package

The results in Table 2, model 1, highlight the factors influencing participants' choices of cigarette packs perceived as less risky to health. The type of warning image had a significant impact, with emotionally charged images, such as the fetus and the foot, strongly influencing participants' decisions. These findings suggest that graphic and emotionally evocative content can effectively shape risk perceptions.

Background color also played an important role in decision-making. Packs with lighter tones were less likely to be chosen, while darker backgrounds appeared to enhance the salience of the warning images, reinforcing the perception of health risks. This indicates that visual design elements, such as color contrast, can significantly affect how warnings are perceived.

In contrast, the salience of the first package presented in the choice set did not significantly influence participants' decisions. Similarly, the position of the package on the right side of the screen did not appear to affect their choices. These results suggest that participants prioritized the visual and substantive attributes of the packages over presentation order or spatial positioning.

Conditional Logit Estimates of Attribute Interactions

As shown in Table 2 (model 2), the results from the conditional logit model reveal that the salience of the first package plays a complex role in participants' decision-making, influenced by both bottom-up and top-down processes. The overall effect of the first package is negative, indicating that participants were generally less likely to select it as the less risky option. However, significant interactions between the first package and certain attributes, such as emotionally charged images and impactful background colors, reveal that these visual elements can modify the salience effect. For example, the combination of striking images, like "Fetus" or "Cadaver," and specific background colors significantly increased the likelihood of choosing the first package. This demonstrates the importance of visual attributes in guiding attention and influencing decisions.

While the "Light Brown" and "Grey" backgrounds did not show significant interactions with the first package, the "Dark Brown" background proved particularly influential. When the first package featured this color, participants were more likely to select it, suggesting that this background enhances the salience of the warning attributes. These findings highlight the role of specific visual cues in capturing participants' attention and shaping their choices.

Conditional Logit Estimates considering Addiction-Driven Control

The results in table 2, model 3, show that age, used as a proxy for addiction, significantly moderates the influence of the salience of the first package on decision-making. The negative coefficient for the interaction between age and the salience effect indicates that older individuals are less influenced by the order of presentation, relying instead on other decision-making mechanisms. Conversely, younger individuals, who are in earlier stages of addiction, are more affected by salience cues, such as the position of the first package, suggesting greater reliance on automatic, stimulus-driven processes.

Table 3. Ordinary Least Squares: Time to Click

INDEPENDENT VARIABLE	
Set Order	-0.036***
	(0.008)
First Package	-0.294*
	(0.156)
Age	-0.008
	(0.006)
First Package*Age	0.0117**
	(0.005)
N=1190.	
* p < 0.05, ** p < 0.01, *** p < 0.001.	
Robust standard errors are reported in parentheses	

The analysis of decision time provides valuable insights into the cognitive effort involved in participants' decision-making processes. The coefficient for the set order indicates that decision times decrease as participants progress through the

experimental tasks. This suggests that participants either become more familiar with the decision-making process or adopt simpler strategies over time.

The interaction term (*First Package*Age*) is significant and positive, suggesting that the effect of selecting the first package on decision time varies with age. Specifically, as age increases, the influence of selecting the first package on decision time becomes less negative, indicating a possible interplay between addiction levels and attentional mechanisms.

Although the coefficient for *First Package* suggests that participants who chose the first package tended to take slightly less time, though this effect is moderated by age. Finally, age as a standalone variable does not show a significant direct effect on decision time, aligning with previous findings that addiction-driven differences may emerge more clearly through interactions with other variables.

5. Discussion

The findings of this study highlight the complex interplay between *bottom-up* and *top-down* processes in decision-making, as well as how visual attributes, attentional mechanisms, and individual differences, such as age and addiction, shape behavior in the context of cigarette packaging warnings.

One of the most notable results is the role of emotionally charged warning images, such as those depicting a fetus or a cadaver, in capturing attention and influencing risk perceptions. These graphic and evocative images appear to activate *bottom-up* processes, directing participants' attention and shaping their decisions based on immediate, stimulus-driven responses (Noar et al., 2016). Similarly, background color played a significant role, with darker tones, such as dark brown, amplifying the salience of warning images through stark contrasts that enhanced their prominence. This aligns with prior findings that darker colors are often associated with gravity and danger (Adams & Osgood, 1973; Kaya & Epps, 2004), underscoring the importance of strategic visual design in risk communication (Hammond, 2011).

Interestingly, while the salience of the first package did not have a significant direct effect on decision times, the interaction with age was significant. This suggests that

the effect of salience on decision-making is moderated by age: younger participants, who are less addicted, are more likely to rely on *bottom-up* cues such as salience, while older participants, with more entrenched habits, tend to prioritize *top-down* evaluations. This highlights the dynamic interplay between addiction, age, and attentional control mechanisms.

Age and addiction introduce additional layers of complexity to these dynamics. Older participants, with higher levels of nicotine dependence and more entrenched habits, demonstrated a stronger reliance on *top-down* mechanisms, driven by pre-existing preferences and cognitive evaluations. Conversely, younger participants, who are less addicted, were more susceptible to *bottom-up* cues, such as the salience of the first package or emotionally charged images. These findings highlight the importance of tailoring interventions to demographic and addiction profiles, as younger individuals may be more responsive to visual salience strategies, while older individuals may require approaches targeting cognitive and habitual processes (Goldstein & Volkow, 2011; Bickel et al., 2014).

Temporal dynamics also played a significant role in shaping decision-making. As participants advanced through the experimental tasks, decision times decreased, suggesting an adaptive process characterized by increased familiarity or reduced cognitive effort. The significant decrease in decision times with task order aligns with learning or fatigue effects, as previously observed (Campbell et al., 2015; Czajkowski et al., 2014; Day et al., 2012). However, the interaction between age and salience underscores the need to consider how individual differences modulate attentional processes and cognitive effort during decision-making.

Together, these results illustrate the dynamic interaction between *bottom-up* and *top-down* mechanisms in decision-making. While visual salience plays a critical role in capturing attention and influencing initial responses, deliberate cognitive processes often dominate in contexts requiring the evaluation of substantive content. This nuanced balance provides valuable insights for designing interventions aimed at influencing behavior across diverse demographic and addiction contexts.

6. Conclusions

This study contributes to the understanding of how *top-down* and *bottom-up* mechanisms interact in decision-making, with a focus on the effectiveness of health warnings on cigarette packaging. The results emphasize the critical role of visual elements, such as emotionally evocative warning images and impactful background colors, in capturing attention and shaping risk perceptions. Dark brown backgrounds and graphic warning images were particularly effective in activating *bottom-up* processes, demonstrating the potential of strategic design to disrupt habitual behaviors and encourage healthier choices, especially among younger, less addicted individuals.

At the same time, the study highlights the limitations of *bottom-up* salience in isolation. For older, more addicted individuals, decision-making was dominated by *top-down* mechanisms, reflecting entrenched habits, cognitive biases, and reliance on pre-existing preferences. This suggests that interventions for this group should focus on addressing deeper cognitive processes rather than relying solely on visual salience.

The interplay between *bottom-up* and *top-down* processes is further complicated by temporal dynamics, as participants adapted their decision-making strategies over time. This adaptability underscores the importance of considering how individuals balance attentional effort with task complexity in real-world contexts, where habitual and emotional factors may amplify the dominance of *top-down* control.

From a public health perspective, these findings provide valuable insights for designing regulatory strategies tailored to different smoker profiles. Younger smokers may respond more effectively to visually salient elements, while interventions for older, more addicted populations may need to target cognitive and habitual processes. In countries like Uruguay, where plain packaging laws and advertising restrictions limit the scope for visual design innovations, these insights are particularly relevant.

Ultimately, this study advances our understanding of how visual salience and cognitive control mechanisms shape decision-making. By tailoring health warnings

to leverage the interplay between *bottom-up* and *top-down* processes, policymakers can design strategies that maximize public health impact and effectively reduce smoking prevalence.

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Ethics approval

This study protocol was approved by the Ethics Committee of the School of Psycology of the Universidad de la República, Uruguay.

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