IN DEPTH, BREADTH-FIRST OR BOTH? CHARACTERISING THE INFORMATION SEARCH PROCESS IN A PUBLIC TRANSPORT SP EXPERIMENT

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Palabras clave: Information search process , Breadth-first searches, Click-tracker , Public transport SP

RESUMEN

El desarrollo y la innovación en la modelización de la elección discreta han estado dominados por los enfoques de maximización de la utilidad aleatoria, debido a su facilidad de aplicación y su gran interpretabilidad económica. Sin embargo, este modelo asume que los responsables de la toma de decisiones realizan un proceso de búsqueda de información en profundidad de forma implícita e instantánea. En particular, no se ha investigado en detalle si el proceso de búsqueda de información de los usuarios de transporte es en profundidad o en amplitud en un contexto de elección de transporte público, una laguna que esta investigación pretende cubrir. Para ello, se ha caracterizado el proceso de búsqueda de información de los usuarios del transporte público mediante encuestas de preferencias declaradas con seguimiento de clics. En concreto, se diseñaron y aplicaron tres encuestas de SP pivotadas relativas a viajes en hora punta de la mañana, variando en el número de alternativas y atributos (áreas de interés mostradas: AOI). Estos valores se mostraron como un tablero de información, en el que sólo es visible un atributo a la vez, y se registraron los clics para evaluar el proceso de búsqueda de información de los encuestados. Los resultados permiten extraer tres conclusiones principales. En primer lugar, predomina el patrón de búsqueda de información en función de la amplitud, independientemente de los AOI mostrados. En segundo lugar, se realizan más búsquedas que la cantidad de información mostrada y este valor aumenta a un ritmo decreciente a medida que aumentan los AOI. En tercer lugar, las transiciones más probables durante el proceso de deliberación son las que surgen de las búsquedas en amplitud. En resumen, las pruebas encontradas sugieren que existe un predominio de las búsquedas en amplitud, por lo que el modelo RUM no podría describir adecuadamente el proceso de deliberación y que los supuestos de los modelos RRM o DFT serían más apropiados para estos fines.

1. INTRODUCTION

In the first investigations of consumer behaviour, there was no notion of the decision-markers' deliberation process. Under classical consumer economic theory, the process was vaguely described as a comparison of alternatives, which are defined from individuals' subjective valuations of attributes, following some decision rule. In contrast, the area of psychology had already laid a more solid base of the sub-processes involved before choosing an alternative. For example, Engel et al. (1968) mention that individuals go through certain stages before making their choice. First, decision-makers must realise they have a lack or problem related to an election. Second, they must search for information through their previous experiences or acquire new information with a processing cost. Finally, with the data collected, they must evaluate the alternatives with a decision rule and a subsequent choice.

Although discrete choice models have generally incorporated the stages involved in the deliberation process, they have not focused on a sub-process vital in decision-making. This corresponds to how individuals acquire external information and how they process it to make their decision, that is, the information search process.

The **Information search process** is defined as the stages where an individual performs cognitive tasks, such as searching their memory, acquiring new information and processing the data to carry out their choice (Payne et al., 1992; Riedl et al., 2008). Figure 1, Xie et al. (2019) presents this process that could be incorporated into discrete choice models.

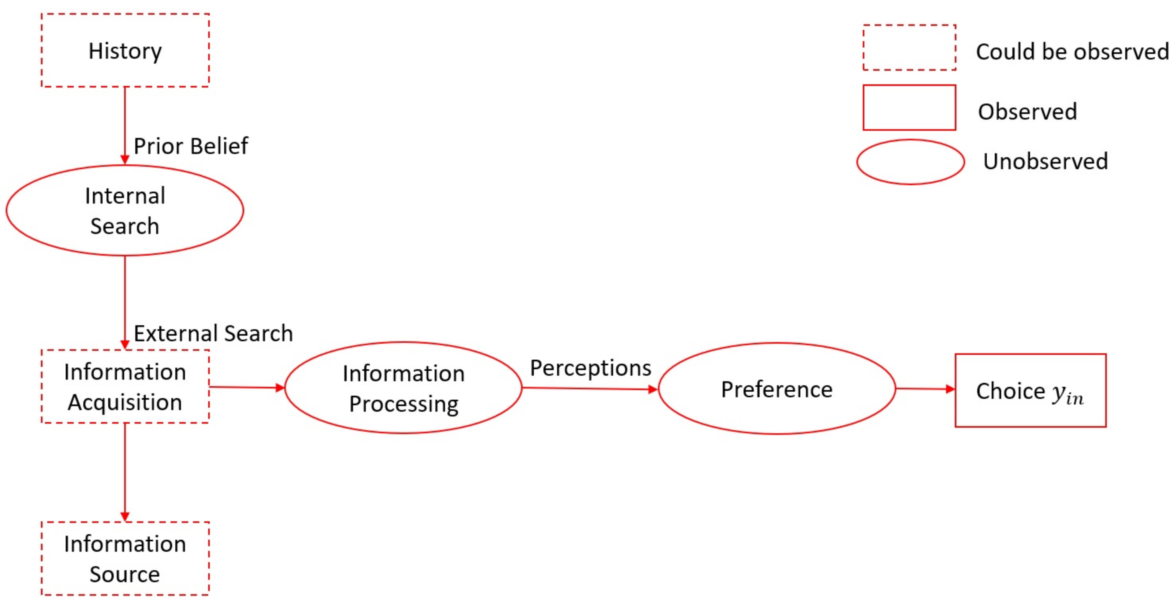

Figura 1: The information search process Xie et al. (2019).

On the one hand, there is the internal search related to retrieving information stored by individuals. Quite a few studies have been conducted to try to understand this process, but it is still unclear how to apply the findings of people's memory in choice models. On the other hand, there is the external search, which corresponds to the stage of acquisition and processing of new information that individuals obtain from external sources (Hulland y Kleinmuntz, 1994). According to Schulte-

Mecklenbeck et al. (2017) this sub-process is defined by the fixations on the attributes during the deliberation time that the decision-maker performs before making the choice. The transitions between these attentions allow the construction of the information search patterns that individuals perform prior to the choice.

Therefore, efforts will be made to understand, analyse and characterise the external information search process performed by public transport users. This is crucial for modelling discrete choices since ignoring the real dynamics behind this process will result in inconsistent model parameter estimators due to endogeneity (Guevara, 2015). Specifically, four different patterns of information search are considered in the analysis that depend on the transitions of the attributes addressed by the decision-makers in a sequential manner. Definitions similar to Bettman y Jacoby (1976); Payne (1976); Johnson et al. (2008); Noguchi y Stewart (2014); Jiang et al. (2016). The figure 2 shows the information search patterns adopted in the different discrete choice models (Inspired from C. Chorus (2012)). The solid arrows represent the conceptualisations, and the dotted arrows represent the information search process and comparisons of alternatives.

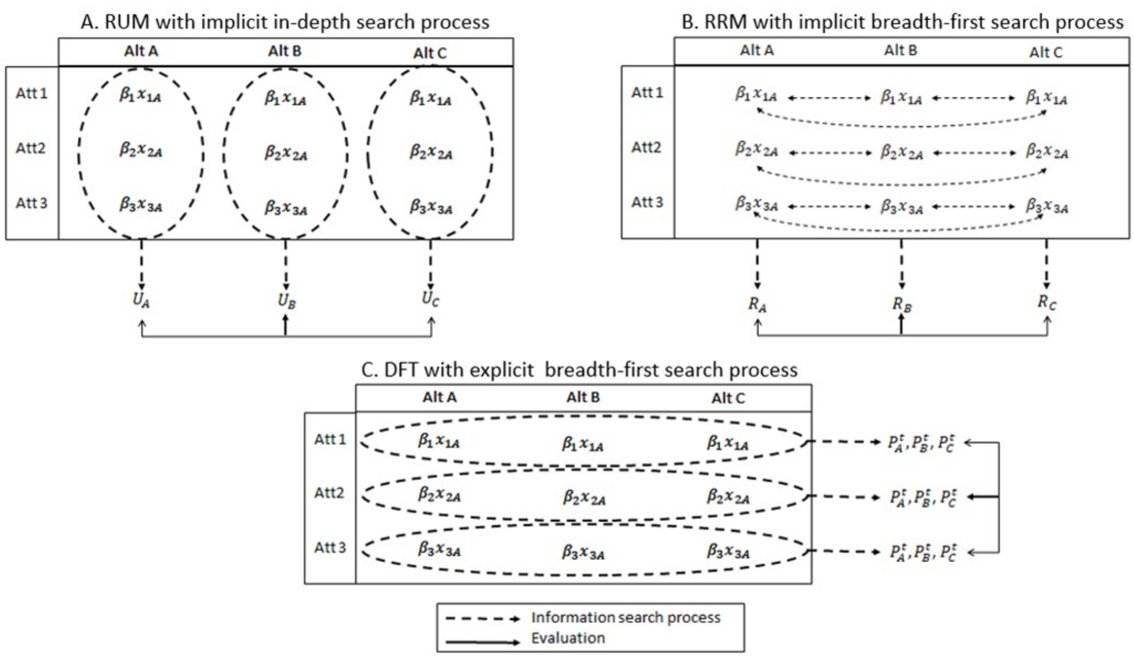

Figura 2: Choice process based on RUM (A), RRM (B) and DFT (C).

Depth search occurs when the individual conceptualises all the attributes of an alternative before making comparisons with the rest of the options. Thus, attention is expected to fluctuate under different attributes but within the same alternative. The RUM models implicitly include this pattern in the calculation of the choice probabilities since it is assumed that individuals construct the utilities of the alternatives considering the value of all available attributes before choosing.

Breadth-first search occurs when the individual focuses on a particular attribute and simultaneously updates the value of all available alternatives for comparison. Therefore, it is expected to focus more on one attribute, and transitions occur more frequently between the alternatives. This pattern has been incorporated into different discrete choice models. On the one hand, the Random Regret

Model (RRM) implicitly includes it in the modelling since the probabilities of choice depend on the regret calculated through the bilateral comparisons of attributes (C. G. Chorus, 2010). On the other hand, the Decision Field Theory (DFT) model explicitly includes this pattern since updating preconceived preferences during the deliberation process is made concerning one attribute at a time (Hancock et al., 2018). It should be noted that this behaviour has been evidenced and supported by the findings of Noguchi y Stewart (2014), which indicate that comparisons of a pair of alternatives under the same attribute dimension occur more frequently. This is why psychological choice models should be modelled in such a way.

Unusual searches occur when attention is more erratic than usual. On the one hand, the adjacent diagonal searches capture the transitions that occur towards contiguous attributes and alternatives. In contrast, non-adjacent diagonal transitions occur when attention goes between non-contiguous attributes and alternatives that imply greater cognitive cost.

It should be noted that the search for attribute information is a mental process for decision-makers and is difficult to capture unless ad hoc **Process Data Surveys** are used. Also, these instruments are typically designed to validate different theories that test the different predictions made by each theory within the same decision space. Traditionally, Revealed Preference (RP) and Stated Preference (SP) surveys have been used to capture the data needed to estimate discrete choice models and test hypotheses raised. The development of these types of surveys has been useful in understanding the choices of individuals, estimating models and being able to calculate the valuations involved in the choice process. However, they have not been able to show the cognitive process involved in decision-making. As a result, researchers began to focus on process tracing methods to evidence the underlying cognitive stages involved (for a recent review, see Schulte-Mecklenbeck et al. (2017)).

In the first experiments on process tracing methods, the attributes considered by the respondent for decision-making were manually recorded. For example, Payne (1976) constructs an apartment choice situation as information boards (IB). In these, the values of the attributes of the alternatives are not available, and the decision-maker can access the information through an **Area Of Interest** (AOI_{kj} represents the k-th attribute of alternative j) that he/she wants to know at a time. Following the same line, Jacoby et al. (1977) manually record information searches made by respondents facing a purchase situation.

Around the same time, eye-tracking began to be implemented to capture process data. Using the proper equipment, gaze metrics such as fixations, location, duration, and direction of the saccades, among others, can be passively stored (see Glaholt y Reingold (2011) for a detailed review). Russo y Rosen (1975), record gaze fixations in a used vehicle choice situation and store the information in a computer. Given the excessive degrees of freedom to analyse the information collection, how expensive this equipment is, and the impossibility of having several respondents simultaneously, efforts began to focus on mouse movement analysis.

Johnson et al. (1989) constructs the MouseLab online tool that allows configuring different choice situations as information boards to capture the mouse movements made by decision-makers to access hidden attributes before the election. Currently, the lines of research focus on developing, implementing and improving instruments that capture process data online, together with reducing the costs involved. Some examples are Yang y Krajbich (2021) who perform eye-tracking using the respondents' camera. This work will focus on implementing and applying surveys that capture data from online click-tracking processes.

The paper is structured as follows. Section 2 details the design, implementation and application of the click-tracker survey to public transport users. Finally, section 3 discusses the results and section 4 describes the main findings and conclusions of the work.

2. CLICK-TRACKER SURVEY

For studying the information search process, in this research three click-tracking surveys are built that vary in the number of alternatives and attributes displayed as areas of interest (AOI), which are not visible and only one can be displayed at a time, following a Payne (1976)'s information board format. These instruments allow data to be collected from the information search process of choice tasks with different experimental proportions. After the surveys are designed, they are implemented on a web page and evaluated by applying them in a focus group to verify that the sequence of attributes clicked, the time of each click, and the choices in each task are properly obtained. Likewise, to improve the instrument, comments and feedback are received.

2.1. Design

The design of the three instruments applied in this research consists of two parts: revealed preferences (RP) and stated preferences (SP). The first section of the instruments collects relevant sociodemographic information about the decision-maker and typical characteristics of the commute to work by public transport during morning rush hour. In the second section, 8 hypothetical questions of pivoted stated preferences are constructed using the value of mobility attributes previously obtained from each respondent.

The difference is that the hypothetical questions are displayed as information boards and click tracking (CT) is performed to capture the AOIs that decision makers attend to in the SP section, until the choice is made. This methodology allows addressing the research concerns since, through click tracking, it is known which attribute of a certain alternative is attended at a time and how the transitions between them occur, being able to evaluate all the intermediate search processes that operate on the available information to reach the final decision (Bröder et al., 2013; Glöckner y Herbold, 2011). In addition, the Design of Designs approach proposed by Hensher (2004) is followed since a series of studies use it to analyse the behaviour of the choices when the dimensions of the experimental design are varied. In turn, this allows verifying if the information search process varies.

Therefore, each participant is shown one of three possible choice situations that vary according to the number of alternatives or attributes available: CT23 (2 alternatives with 3 attributes), CT26 (2 alternatives with 6 attributes), and CT36 (3 alternatives with 6 attributes) increasing by 6 AOIs shown, respectively. The information board format is applied in surveys, where the value of the attributes of the different alternatives are not available and where, in order to access the relevant information, the decision-maker has to click on each AOI. It should be noted that only one attribute at a time remains visible, this is constructed in this way to capture how many times the attributes are attended and how much their values are remembered. The result of these surveys corresponds to the sequence of attributes attended to, which is a valid approximation of the information search process and allows conclusions to be drawn about the psychological constructs (Just y Carpenter, 1980).

Figure 3.A shows the section of socioeconomic questions, figure 3.B shows the mobility questions (revealed preferences), and figure 3.C shows an example of a choice task; containing 3 alternatives and 6 attributes in a click-tracked information board format (declared preferences).

Figura 3: A) Socio-economic questions. B) Revealed preference questions: Mobility. C) Revealed questions: Information board with Click-Tracking.

The profile factors of each hypothetical question, which allow pivoting the attribute values obtained in the revealed preferences section, are obtained from a D-efficient experimental design using the Ngene software (Ngene, 2018). For this process, an MNL model was considered with attribute parameters obtained from previous studies for the city of Santiago, Chile. Given that a pivoted survey is proposed, a Monte Carlo experiment was carried out allowing to verify that the parameters were recovered when estimating an MNL model using simulated mobility characteristics of 100 individuals and subsequent application of the survey with the pivoting factors. Then, the pilot survey was applied to a focus group. It raised questions related to the attributes considered, whether these allowed to correctly model the public transport route choice, and how intrusive the information board format with click tracking is. All these answers were considered to achieve a good design so as not to reach inconclusive results or spend unnecessary efforts and resources in order to correct the instruments before the final application.

2.2. Participants and procedure

The 3 surveys were implemented in a web domain (`http://www.click-tracker.cl`), and the database is stored in MySQL. Strictly, the database collects, in each of the questions answered by the respondents, socioeconomic characteristics (age, gender, educational level, employment status, type of fare, number of days they use public transport, income and the number of people with whom they cohabit); the Values of the attributes that define the typical morning commute(walking time, waiting time, travel time, cost, number of transfers and general availability of seats on the trip); and, the sequence of clicked attributes, plus the chosen alternative, along with the duration of each click.

The click-tracking surveys (CT23, CT26, CT36) were applied in September 2021, obtaining a sample of 265 respondents, where only 251 individuals answered adequately. Public transport users were randomly recruited in different crowded locations in the city of Santiago, such as bus stops or subway stations, indicating that by answering the survey, they would be entering into a drawing for a $25 Gift card prize.

Once the field stage is over, the information is processed, eliminating the observations that had some error or anomaly in the answers. This step was necessary because the respondents could have responded randomly just to get the incentive mentioned above, or they could have entered the values wrongly in the stage of revealed preference questions.

Finally, the sample allocation resulted in a fairly balanced allocation, having 91 responses for CT23; 81 for CT26 and 79 for CT36. The mean age of the participants was 25.7 years with ($sd = 10{,}04$). 144 of the total sample were students, and 122 were men. Socioeconomic characteristics did not differ significantly in the 4 surveys in terms of age ($F = 0{,}89,\ p = 0{,}45$) gender ($\chi^2 = 1{,}13,\ p = 0{,}77$) or payment system ($\chi^2 = 1{,}10,\ p = 0{,}65$).

3. RESULTS

3.1. Amount of information search

The information searches carried out by the respondents before the choice was calculated, and the mean values, together with their standard deviation, are summarised in the table 1. On average, more information searches were carried out than the total number of areas of interest shown in each instrument, realising that public transport users do not capture the value of the attributes in the first instance and need to reconceptualise these values to include them in their utilities or preferences. Moreover, it can be seen that this construct grows significantly as the number of attributes or alternatives increases. On the other hand, when considering the AIS normalised by the AOI in the different surveys and performing a test of means, it can be noted that a more significant increase in the number of searches is generated when attributes are added ($t = 6{,}36$) compared to when the alternatives are increased ($t = 2{,}71$). Therefore, the amount of information search increases at decreasing rates with the AOIs shown in the surveys, but to a greater extent when attributes are added.

Survey	J	K	AOI	AIS	AIS/AOI
CT36	3	6	18	19.5 (11.8)	1.1 (0.7)
CT26	2	6	12	14.6 (10.1)	1.2 (0.8)
CT23	2	3	6	9.2 (5.4)	1.6 (0.9)
CT	-	-	-	14.4 (10.2)	1.3 (0.8)

Tabla 1: Amount of information search in surveys

The boxplot with the fixations made by the respondents normalised by the amount of AOI corresponding to each survey reinforces the previous finding since it can be seen that the confidence intervals are different from each other. Furthermore, it is shown that less information is sought by AOI when cognitive load increases. Also, the greatest difference is between the CT23-CT26 surveys, more than the CT26-CT36 surveys, showing that the number of searches intensifies to a greater degree with the attributes increase.

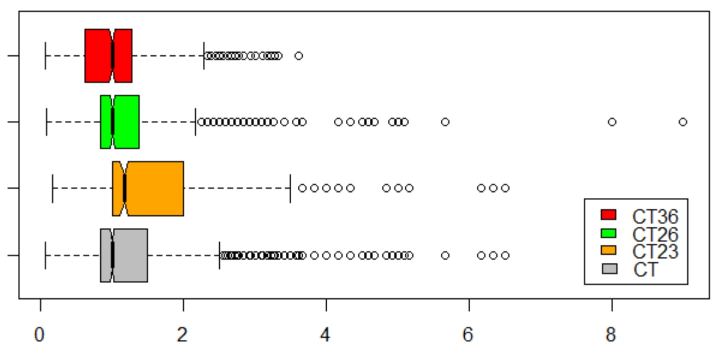

Figura 4: Amount of information search standardised by AOI.

When analysing socioeconomic characteristics, it stands out that male public transport users systematically carry out more information searches than the rest of the population in all the surveys (p-value$< 0{,}001$ in all cases). On the other hand, when analysing according to the fare paid, the students who have a discount carry out significantly more information searches than the users who pay a total fare in the CT23 and CT36 surveys (p-value$< 0{,}001$ in both cases). These findings are in line with those found by Kwak et al. (2015). Same as those authors, it was found that the number of searches performed increased as the experiment progressed and this increase was much more pronounced for adults. In particular, for this work, the adults pay a total fare. This shows that those surveyed with a reduced fare (Students/young people) carry out a more complete and intense information processing before making their choice.

However, this construct reveals only the number of searches and not the areas of interest most attended by the respondents (attributes and alternatives). In the following subsections, we show this analysis to identify if it is necessary to include different attention weights on the attributes. The attention to attributes can be seen in figure 5 and the fixations towards the alternatives can be observed in figure 6.

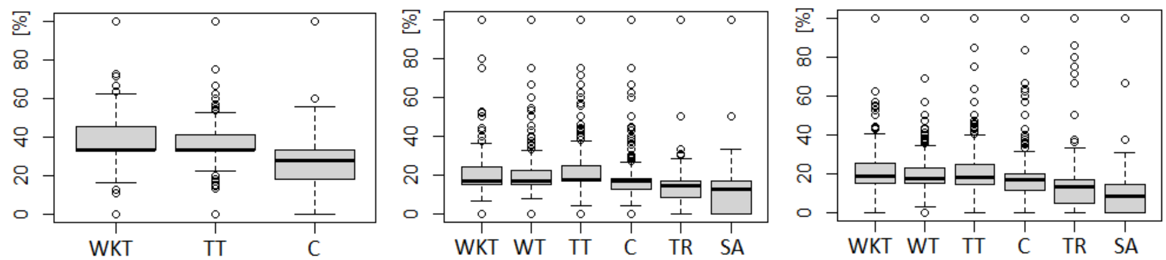

Figura 5: Attention on attributes in CT23 (a), CT26 (b) y CT36 (c).

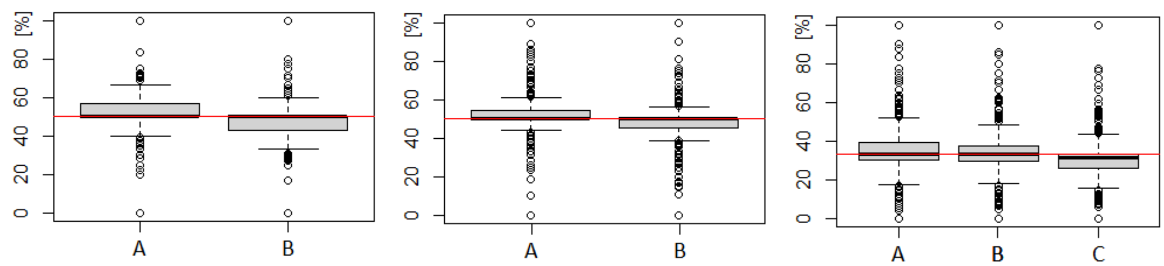

Figura 6: Attention on alternatives in surveys CT23 (a), CT26 (b) and CT36 (c).

To close this construct analysis, it can be commented that these results are consistent with those found by Meißner et al. (2020), who conclude that the dimensions of the election situation affect the information search process. The findings show that increasing the number of attributes and alternatives leads to an increase in the information search and induces certain filtering of attributes. The novelty of this research lies in the fact that these results are replicated in the public transport route choice SP context, and a greater impact is evidenced in the deliberation process when adding attributes to the number of alternatives.

3.2. Filtration

Filtration corresponds to the AOIs that are not considered during the deliberation process before the final choice. Figure 7 shows the percentage of areas of interest that were not fixed during the deliberation process in each of the surveys presented. In this image, it can be seen, in general, that increasing the number of alternatives or attributes leads to a significant increase in filtered information. This had already been evidenced with the boxplots in the figures 5 and 6, in which they show observations that did not fix certain attributes or alternatives at any time. Likewise, it can be shown that the percentage of unattended areas of interest increases as the decision-maker advances in the choice tasks.

As a final comment, from the figure 8, it can be seen that there are null percentages of fixations on some attributes. These values show that the respondents did not pay attention to these attributes to

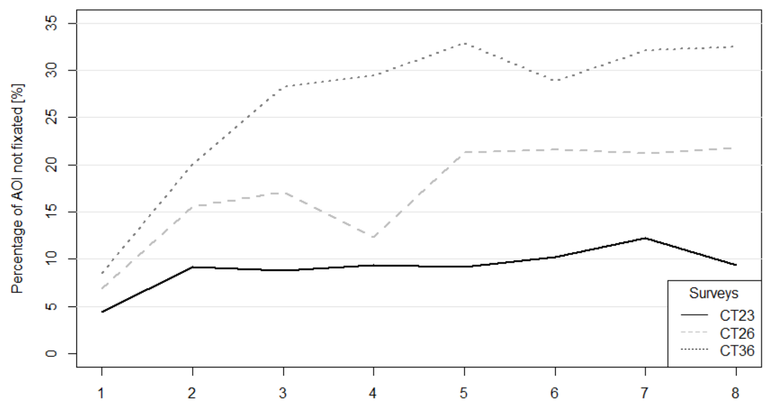

Figura 7: Percentage of areas of interest not fixed in surveys.

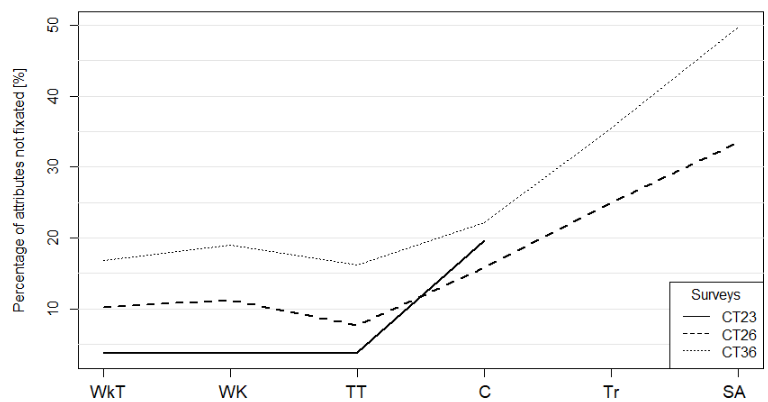

Figura 8: Percentage of attributes not fixed in surveys.

make their choice throughout the deliberation process. In other words, in a model that considers all the attributes for the construction of utilities or preferences, there would be errors in calculating probabilities of choice since it would not capture the true data generation process, and the estimation of population parameters would not be adequate.

3.3. Information search pattern

This construct indicates how respondents acquire and process information during the deliberation process. First, it is possible to calculate the number of respondents who perform each information search pattern before the election at least once to show that there is heterogeneity in the deliberation process. For example, in the Breadth-First row of the 2 table, it is shown that most of the respondents carry out this pattern, and there is a predominance in all the surveys. Furthermore, it can be seen that there is an increase in this type of search when more attributes are added but a decrease with the rise of alternatives. This behaviour is repeated similarly with adjacent diagonal searches in the different surveys.

Concerning the rest of the patterns, the behaviour is unclear since depth searches are intensified

ISP	CT23	CT26	CT36
Depth	62 %	88 %	71 %
Breadt-First	87 %	95 %	92 %
Adj. Diagonals	80 %	80 %	40 %
Non-Adj. Diagonals	29 %	27 %	76 %
N	632	648	728

Tabla 2: Percentage of respondents who perform at least once the ISP.

in the CT26 survey, and non-diagonal adjacent ones decrease. This behaviour may be since this informative board shows the areas of interest in a more rectangular horizontal format than the rest of the surveys. Similar results to Meißner et al. (2020), who show that a survey with 3 alternatives decreases depth searches, favouring other patterns when compared to one with two alternatives (being both surveys with 6 attributes).

In general, more than 45 % of the searches during the deliberation process were carried out following a breadth-first pattern in all the applied instruments. Moreover, it can be noticed that this behaviour is intensified regardless of the areas of interest displayed. These results show for the first time that the information search process of route choice is strongly constructed as a sequence of transitions on attributes of the same dimension. This is followed by patterns of adjacent diagonals and depth searches that depend on the number of attributes and alternatives displayed. Therefore, more experiments must be conducted to determine if there is a systematic relationship between the proportions of these types of searches.

These empirical findings are consistent with comments by Kwak et al. (2015), who mention that information search patterns are complex and mixed. In the present work, progress is made in presenting choice situations with multiple attributes and alternatives, which allow supporting the previous idea. Furthermore, these results contradict the conclusions from Su et al., (2013), which comments that decision-makers construct their utilities solely as weights and sums without any more complex heuristic process. For example, selective use of information about alternatives and simple comparisons.

3.4. Transition Matrix

Transition matrices show the relative frequencies between consecutive fixations. An example for the CT36 is shown in figure 9, which reveal the probabilities that respondents attend a particular area of interest in timestep t conditional on a previous AOI. From the outcomes, two important findings can be obtained. First, it is possible to know the aggregate information search patterns that predominate among the participants to reach their final decision. Secondly, it can empirically know the probability of observing an attribute in the next step in the information search process. This allows to include how the evidenced information is acquired and its attention weights in the model to be proposed, which incorporates the sequential evaluation of attributes. Therefore, this modelling allows for the first time to adequately integrate the updating of utilities or preferences for the subsequent comparison of alternatives and choices.

		Attribute observed in step t+1																		
		Alternative A						Alternative B						Alternative C						
Attribute observed in step t		WKT	WT	TT	C	T	SA	WKT	WT	TT	C	T	SA	WKT	WT	TT	C	T	SA	
Alternative A	WKT Walking Time	0	2	0	0	0	0	4	0	0	0	0	0	0	0	0	0	0	0	7%
	WT Waiting Time	1	0	2	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	7%
	TT Travel Time	0	1	0	2	0	0	0	0	4	0	0	0	0	0	1	0	0	0	7%
	C Cost	0	0	0	0	1	0	0	0	0	3	0	0	0	0	0	1	0	0	6%
	T Transfer	0	0	0	0	0	1	0	0	0	0	2	0	0	0	0	0	0	0	5%
	SA Seat Avaibility	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	3%
Alternative B	WKT Walking Time	1	0	0	0	0	0	0	2	0	0	0	0	4	0	0	0	0	0	7%
	WT Waiting Time	0	1	0	0	0	0	1	0	2	0	0	0	0	3	0	0	0	0	7%
	TT Travel Time	0	0	1	0	0	0	0	1	0	1	0	0	0	0	3	0	0	0	7%
	C Cost	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0	3	0	0	6%
	T Transfer	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0	2	0	5%
	SA Seat Avaibility	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	3%
Alternative C	WKT Walking Time	1	2	0	0	0	0	1	0	0	0	0	0	0	2	0	0	0	0	7%
	WT Waiting Time	0	1	2	0	0	0	0	1	0	0	0	0	1	0	2	0	0	0	6%
	TT Travel Time	0	0	1	2	0	0	0	0	1	0	0	0	0	1	0	1	0	0	6%
	C Cost	0	0	0	1	2	0	0	0	0	1	0	0	0	0	0	0	1	0	5%
	T Transfer	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	4%
	SA Seat Avaibility	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2%

Figura 9: Matriz de transición de encuesta CT36.

Generally, when there are few AOIs, participants make as many transitions as possible between areas of interest (without aggregating based on search pattern type). It is also evident that, by increasing the cognitive load shown, the respondents favour certain transitions and heuristics. Regardless of the above, the information search in breadth-first prevails over the rest of the possible patterns. On the other hand, the second pattern that intervenes in the process depends on the number of attributes and alternatives shown and could be depth for boards with more attributes than alternatives and diagonals with more alternatives than attributes. These results are consistent with those discussed previously.

These findings are consistent with those discussed in Bault et al. (2016). This research shows that the transitions are not independent and that the gaze patterns are consistent. This is because they found many transitions between gains or gains probabilities across the alternatives (breadth-first), then glanced between the gains and their associated probability (depth). Second, the participants preferentially explored from left to right, similar to what was found in these surveys. In addition, it is in line with and reinforces what was found in Noguchi y Stewart (2014), who argue that each comparison of alternative pairs occurs under a single attribute dimension. In light of the results, it is possible to conclude that: Psychological choice models must include an information search process in breadth-first, with a certain degree of freedom that allows capturing other secondary patterns, such as depth or diagonals used to a lesser extent by decision-makers.

3.5. Search pattern order

This construct is defined as the pattern of information searching that predominates in each step of the deliberation process. This measure is obtained from the frequencies of the patterns throughout the deliberation time of all participants, making it possible to show the predominance of in-depth, breadth-first or few common searches. Figure 10 plot the curve that represents the times in which respondents performed the different information search patterns in CT23 survey; at each step of the deliberation process. From this analysis, it is possible to deduce the order in which these types of searches are carried out.

Fom the CT23 survey (figure 10), it can be seen that there is a greater number of respondents who

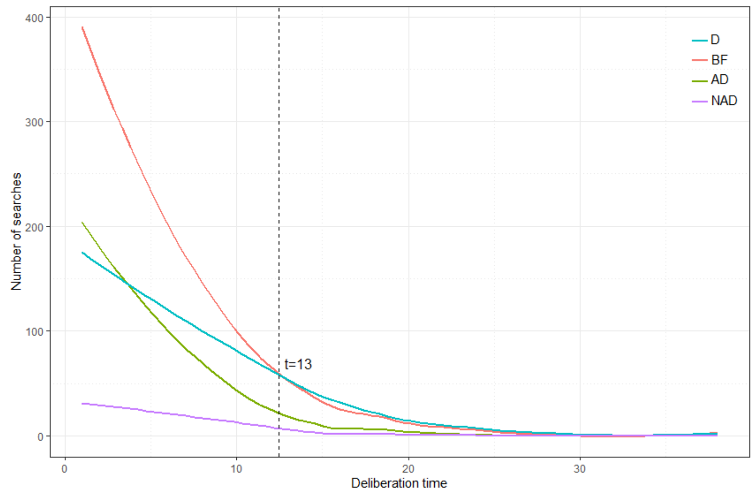

Figura 10: Information search pattern order in CT23.

preferably perform breadth-first searches; in the first instance, and this is maintained during most of the deliberation time (up to t=13 there are 83.5 % of respondents who have already decided on an alternative). Then until t=4, it is followed by adjacent diagonal searches and depth transitions for the rest of the time (until t=13). The non-adjacent patterns are smaller and correspond to the minimum value in 92 % of the deliberation time concerning the other transitions. It should be noted that more depth comparisons are made as the deliberation time progresses, which can be evidenced for two reasons. First, the slope of the curve is less than the decay rate of the breadth-first transition. Secondly, the number of depth searches is greater than the rest of the patterns from the first third of the process onwards.

This pattern is similar in the rest of the surveys, where breadth-first searches dominate and depth-first searches predominate as decision-makers perform survey searches.

3.6. Duration

Duration is defined as the average time dedicated to each fixation made during the deliberation process. The boxplots in figure 11 show the average information search time for each of the 8 choice tasks of the CT23, CT26 and CT36 surveys, respectively. Also, the average of these values is highlighted in red. These values are obtained as the amount of time the clicked areas of interest remain visible. From these values, it can be seen that there is a steady decline in average click durations as respondents progress through the survey. This suggests two possible reasons. The respondents acquire knowledge to use the instrument and click faster, or participants begin to memorise the location of the relevant areas of interest to make their choice and perform certain information search heuristics acquired during the previous answered tasks.

Therefore, the duration is not constant during the deliberation process and contradicts the results shown by Stewart et al. (2016). This is because the experiments carried out in this work are more complex. As has been evidenced from the different constructs, different information search pat-

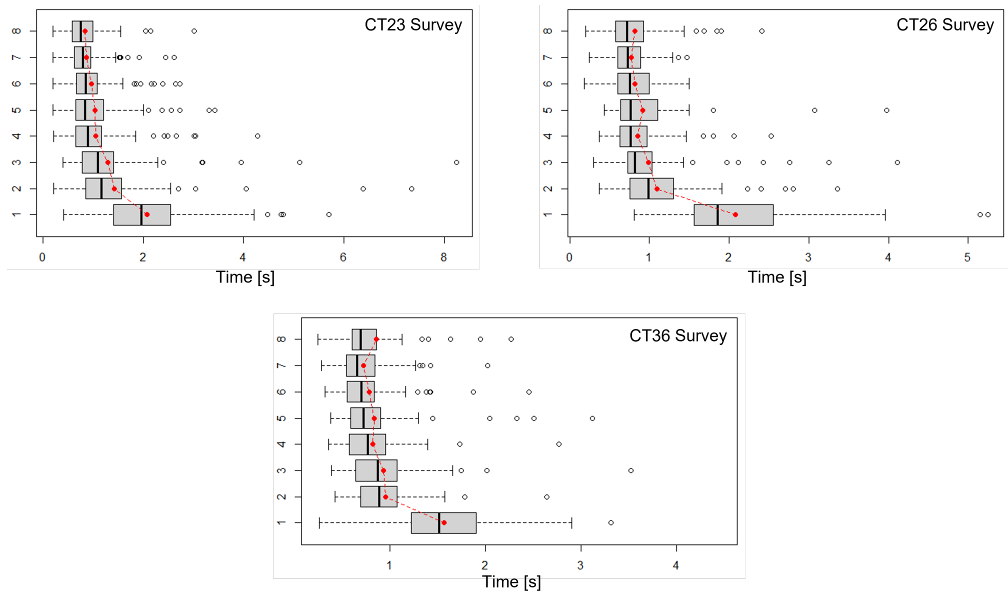

Figura 11: Average duration of searches in each choice task in CT surveys.

terns are involved, showing instability in information processing. This implies differences in the duration of information acquisition and processing (Rayner et al., 2012). However, short durations and variability throughout the deliberation are more consistent with automatic processes such as accumulating models (Glöckner y Herbold, 2011).

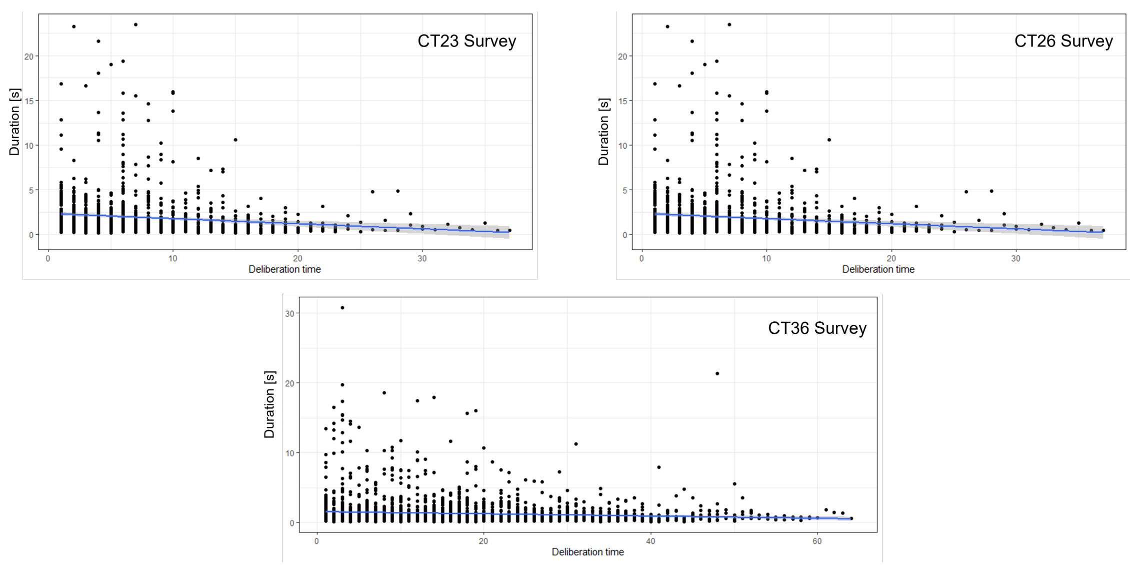

Figura 12: Fixation durations throughout the deliberative process in surveys.

4. CONCLUSIONS

In this research, instruments were designed and implemented to collect evidence of the information search process. Specifically, participants had to answer stated preference (SP) surveys of public transport route choice pivoted to the characteristics of their morning commute. These tools, in addition to collecting data related to the socio-economic characteristics, mobility and choices of decision-makers, allow us to capture with great certainty the sequences of areas of interest attended that motivated them to make their choices through click-tracking and gaze.

In more detail, psychological constructs were defined to unravel the information search process that respondents performed prior to their choices. Within the analyses made in this section, the following five findings stand out:

The first thing to note is that the vast majority of public transport users search for information in Breadth-first and that the type of secondary pattern depends on the number of alternatives and attributes (AOI) displayed in the choice situation. On the one hand, as the AOIs increase, people search more frequently for information following a breadth-first behaviour. On the other hand, it was found that, in general, they search in Breadth-first in the first stage of the deliberation process and then in Depth in the last searches to validate the chosen alternative.

Next, it was found that users performed more searches for information than the number of areas of interest shown in each instrument. Moreover, the number of fixations increases at decreasing rates the more AOIs are presented and this construct increases to a greater magnitude when more attributes than alternatives are added. In addition, it was found that male and students users have a more complex deliberation process because they make more fixations than the rest of the population.

Finally, It was then possible to show that filtration increases as respondents progress through the questions, independent of the number of alternatives and attributes. It was also found that there are attributes never attended to during the deliberation process. Therefore, the current compensatory models are imperfectly estimated, as they consider that agents have complete information.

Although some of these results presented in this research corroborate previously presented in the psychology and cognition literature, this is the first time that we show a detailed analysis of these constructs applied to a public transport route choice SP situation. Overall, the findings allow us to conclude that the information search process is part of a heuristic, heterogeneous, complex and mixed deliberation process, which depends on the dimensions of the choice tasks and the characteristics of the respondents. However, there is a predominance of breadth-first searches, i.e. the evaluation of the information is done through comparisons of alternatives under a particular attribute. Therefore, the conclusions of Noguchi y Stewart (2014); Venkatraman et al. (2014); Kwak et al. (2015); Meißner et al. (2020) can be extended to complex situations of public transport route choice, in which multiple attributes and alternatives are involved. However, the methodology used has been criticised for increasing the extent of distortion, as decision-makers have to overcome an artificial barrier to access the information (Schulte-Mecklenbeck et al., 2017). Therefore, it is proposed to carry out this analysis using eye-tracking, in order to verify that these results are independent of the instrument used.

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