

REVEALED ATTENTION*

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Abstract

The standard revealed preference argument relies on an implicit assumption that a decision maker considers all feasible alternatives. However, the marketing and psychology literatures provide well-established evidence that consumers do not consider all brands in a given market before making a purchase (Limited Attention). In this paper, we illustrate how one can deduce both the decision maker's preference and the alternatives to which she pays attention and inattention from the observed behavior. We illustrate how seemingly compelling welfare judgements without specifying the underlying choice procedure are misleading. Further, we provide a choice theoretical foundation for maximizing a single preference relation under limited attention.

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1 Introduction

Revealed preference is one of the most influential ideas in economics and has been applied to a number of areas of economics, including consumer theory.¹ According to the standard revealed preference theory, x is revealed to be preferred to y if and only if x is chosen when y is also available (Paul A. Samuelson (1938)). Any choice reversal, therefore, observed both empirically and experimentally, is attributed to irrationality since it cannot be expressed as a preference maximization.

The revealed preference argument relies on the implicit assumption that a decision maker (DM) considers all feasible alternatives. Without the full consideration assumption, the standard revealed preference method can be misleading. It is possible that the DM prefers x to y but she chooses y when x is present simply because she does not realize that x is also available (Daniel Hausman (2008)). For example, while using a search engine, a DM might only pay attention to alternatives appearing on the first page of the results since it takes too much time to consider all the search results. She then picks the best alternative of those on the first page, say y . It is possible that her most preferred item, x , does not appear in the first page. Therefore we, as outside observers, cannot conclude y is better than x even though y is chosen when x is available. Nevertheless, as in the above example, the DM may have a well-defined preference and is maximizing her preference within her bounded understanding of what is available.²

This immediately raises a question: How can we elicit her (stable) preference without the full attention assumption? We consider a DM who picks her most preferred item from the alternatives she pays attention to, not from the entire feasible set. Then we shall illustrate when and how one can deduce both the DM's preferences and the alternatives to which she does or does not pay attention from her observed choices. Furthermore, we illustrate the problem of the welfare judgement without specifying the underlying choice procedure by showing an example where our method and the conservative criterion of Douglas B. Bernheim and Antonio Rangel (2007,

¹Hal R. Varian (2006) provides a nice survey of revealed preference analysis.

²As argued in Robert J. Aumann (2005), this behavior is still considered rational (at least boundedly rational) since she is choosing the best alternative under her limited information of what is available.

2009) result in the completely opposite implication.

The marketing literature calls the set of alternatives to which a DM pays attention in her choice process as the *consideration set* (Peter Wright and Fredrick Barbour (1977)). The formation of the consideration set has been extensively studied in marketing and finance literatures (e.g. John R. Hauser and Birger Wernerfelt (1990); John H. Roberts and James M. Lattin (1991)). It has been argued that due to cognitive limitations, DMs cannot pay attention to all the available alternatives. As Herbert A. Simon (1957) pointed out, being able to consider all possible alternatives is as hard as comparing them for decision makers. Therefore, a DM with limited cognitive capacity (possibly stemming from unawareness as demonstrated in Michelle S. Goeree (2008)³), restricts her attention only to a small fraction of the objects present in the associated market (George J. Stigler (1961), Edgar A. Pessemier (1978), Jeong-wen, Chiang, Siddhartha Chib and Chakravarthi Narasimhan (1998).⁴ In sum, DMs intentionally or unintentionally filter out some alternatives to prevent her cognitive capacity from being overloaded (Donald E. Broadbent (1958)).

The common property in the formation of consideration sets is that it is unaffected when an alternative she does not pay attention to becomes unavailable. This basic property of the attention filter, which is also documented in the psychology literature (Broadbent (1958)), can be interpreted as the minimal condition. This property is trivially satisfied in the classical choice theory where it is assumed that the DM is able to pay attention to all the available alternatives. Additionally, it is normatively appealing especially when a DM pays attention to all of items she is aware of and is unaware that she is unaware of other items. For example, if a PC buyer is not only unaware of a particular PC, but she is also unaware that she overlooks that PC, then, even when that PC becomes unavailable, such a change will not be recognized by her. Therefore, her consideration set will stay the same.

³Robert J. Lavidge and Gary A. Steiner (1961) presented awareness of an item as a necessary condition to be in the consideration set. How unawareness alters the behavior of the DM has been studied in various contexts such as game theory (Aviad Heifetz, Martin Meier and Burkhard C. Schipper(2010), Erkut Y. Ozbay (2008)), and contract theory (Emel Filiz-Ozbay (2010)).

⁴In addition, in financial economics it is shown that investors reach a decision within their limited attention (Gur Huberman and Tomer Regev (2001)). Similar examples can be found in job search (Max D. Richards, John E. Sheridan and John W. Slocum (1975)), university choice (Philip L. Dawes and Jennifer Brown (2005)), and airport choice (Gozen Basar and Chandra Bhat (2004)).

Interestingly, the property is also satisfied when the DM actually chooses the consideration sets by taking the cost of investigation and the expected benefit into account. Suppose the DM excludes x from her consideration. If x becomes unavailable, she has no reason to add or remove any alternative to her consideration set because she could have done so when x was available. Therefore, her consideration set is not affected when x becomes unavailable. Furthermore, this property is also satisfied when the formation is based on many decision heuristics, such as paying attention only to the N-most advertised alternatives or the products appearing in the first page of search results. As a result, our property is appealing from both normative and descriptive point of views.

In this paper, we refer to the consideration sets satisfying this property as *attention filters*. Under this structure, it is possible to elicit the DM's preference whenever a choice reversal is observed.⁵ For example, assume that she chooses x but removing y changes the choice. This can happen only when her consideration set has changed. This would be impossible if she did not pay attention to y . Hence, y must have been considered (*Revealed Attention*). Given the fact that x is chosen while y draws her attention, we conclude that she prefers x over y (*Revealed Preference*). In sum, whenever her choices changes as a consequence of removing an unchosen alternative, the initially chosen alternative is preferred to the removed one.

Given that our identification strategy relies on the particular choice procedure, where she maximizes her preference within her attention filter, it is natural to ask the falsifiability of our model. We show that our model is fully characterized by weakening the Weak Axiom of the Revealed Preference (WARP). This result renders our model behaviorally testable.

Our method to distinguish between a preference and attention/inattention generates several policy implications. For instance, if a product of a firm is unpopular in the market place, there could be two different explanations: (i) the product has a low evaluation by consumers or (ii) it does not attract attention of consumers. Identifying the right reason will lead to different strategies for the firm to improve the sales.

Our paper also contributes to the recent discussion about welfare analysis under

⁵Without any structure on the formation of the consideration sets, any choice behavior can be rationalized by any preference (Hausman (2008)).

non-standard individual behavior.⁶ We elicit the DM’s preference in a positive approach, which is based on a particular choice procedure. Bernheim and Rangel (2009) criticize such an approach by arguing that it is not necessary to explain the behavior to make a welfare analysis. Instead, they make welfare arguments directly from the choice data without assuming any choice procedure (model-free). Particularly, they claim that y is strictly welfare improving over x if y is sometimes chosen when x is available but x is never chosen when y is present. However, this intuitive criteria of welfare analysis is meaningful only if the DM considers all the presented alternatives.⁷ In Section 3, we discuss this issue in detail to illustrate the problem of the naive use of the model-free approach. Indeed, we provide an example where their welfare implication contradicts our revealed preference (hence the actual preference); that is, y is revealed to be preferred to x even when x is strictly welfare improving over y in Bernheim and Rangel (2009)’s sense.

So far we have discussed how one can elicit DM’s preference and consideration sets in our model. In doing so, we impose a relatively weak condition on the formation of consideration sets so that our approach is applicable to a wide range of choice data. As a result, although our model is refutable, it provides an alternative explanation for several frequently observed behaviors that cannot be captured by the standard choice theory: Attraction Effect, Cyclical Choice, and Choosing Pairwisely Unchosen (see Anomalies section). Our explanations for these choice patterns solely depend on limited attention, hence seemingly irrational behaviors can be explained without introducing changing preference. Nevertheless, depending on the intended application, it is possible to analyze this framework under different restrictions on consideration sets (see Concluding Remarks).

There are several related models where the final choice is made after eliminating several items, which can be interpreted as a choice with limited consideration such as applying a rationale to eliminate alternatives (Manzini and Mariotti (2007),

⁶See Attila Ambrus and Kareen Rozen (2010), Jose Apesteguia and Miguel A. Ballester (2010), Vadim Cherepanov, Timothy Feddersen and Alvaro Sandroni (2010), Christopher P. Chambers and Takashi Hayashi (2008), Paola Manzini and Marco Mariotti (forthcoming), Yusufcan Masatlioglu and Daisuke Nakajima (2007), Jawad Noor (forthcoming), Ariel Rubinstein and Yuval Salant (2010)).

⁷Indeed, Bernheim and Rangel (2007) mention that if we know the DM believes that she is choosing from a set that is other than the objective feasible set, we should take it into account for the welfare analysis (Section III B).

Apestequia and Ballester (2008), Nicolas Houy (2007), Houy and Koichi Tadenuma (2009)), focusing only on alternatives a decision maker can rationalize to choose by some other criteria (Cherepanov, Feddersen and Sandroni (2010)) and considering only alternatives belonging to undominated categories (Manzini and Mariotti (forthcoming)). Our model is both descriptively and behaviorally distinct from these models. In addition, unlike our model, these models implicitly assume that a DM considers all feasible alternatives at the first stage and *intentionally* eliminates several alternatives. Therefore, their stories are not applicable to cases where the source of limited consideration is unawareness of some alternatives.

Finally, we would like to compare several other models involving consideration sets in decision theory. Juan S. Lleras, et al. (2010) study a different model of choice under limited consideration where a product attracting attention in a crowded supermarket shelf will be noticed when there are fewer products. While this paper is complementary to our paper, their implications are completely different (see Concluding Remarks for more discussion). Masatlioglu and Nakajima (2009) propose a model of an iterative search where a decision maker cannot consider all alternatives, which can be because of unawareness like our model. The difference is that they emphasize that a consideration set depends on the initial starting point and evolves dynamically during the course of search. In the models of Andrew Caplin and Mark Dean (forthcoming) and Caplin, Dean and Daniel Martin (forthcoming), a decision maker goes through alternative sequentially and, at any given time, chooses the best one among those she has searched. Unlike our model, their “choice process” data includes not only the DM’s choice without time limit, but also what she would choose if she were suddenly forced to quit the search at any given time.

Kfir Eliaz and Ran Spiegler (forthcoming) analyze a market where firms would like to manipulate consumers’ consideration sets by using costly marketing devices. Eliaz, Michael Richter and Rubinstein (forthcoming) study a very concrete and reasonable way to construct a consideration set. Indeed, some of consideration sets we shall present as examples are within their models. However, contrary to our model, in their paper, the decision maker’s consideration set (called *finalists*) is observed and is directly investigated. In our model the consideration set is an object that must be inferred from the DM’s final choice.

The outline of this paper is as follows: Section 2 introduces the basic notations and definitions. In Section 3, we provide two characterizations for the revealed preference and the revealed (in)attention from observed choice data. Section 4 provides a simple behavioral test for our model and discusses the related literature. Then, in Section 5, we illustrate that our limited attention model is capable of accommodating several frequently observed behaviors. Finally the Further Comments and the Concluding Remarks sections conclude the paper.

2 The Model

Throughout this paper, let X be a finite set of alternatives that may be available for a decision maker to choose. \mathcal{X} denotes the set of all non-empty subsets of X , which is interpreted as the collection of all the (objective) feasible sets observed by a third party.

2.1 Attention Filters

In our model, a decision maker picks the best element from those she pays attention to. Our goal is to elicit her preference along with her attention and inattention from her actual choice data. However, this is impossible without any knowledge about her attention and inattention. One can always claim that she picks an alternative because she ignores everything else so one cannot infer her preference at all.

We now propose a property how consideration sets change as feasible sets change, instead of explicitly modeling how the feasible set determines the consideration set. This approach makes it possible to apply our method to elicit the preference without relying on a particular formation of the consideration set. We shall explain that this property is normatively compelling in several situations and is indeed true in many heuristics people actually use in the real life.

Let S be a feasible set the decision maker is facing. She does not pay attention to all alternatives in S . Let $\Gamma(S)$ be the (non-empty) set of elements to which she pays attention. Formally, Γ is a mapping from \mathcal{X} to \mathcal{X} with $\emptyset \neq \Gamma(S) \subset S$. We call it a consideration set mapping. Of all consideration set mappings, we focus on those

having the following property:

Definition 1. A consideration set mapping Γ is an **attention filter** if for any S , $\Gamma(S) = \Gamma(S \setminus x)$ whenever $x \notin \Gamma(S)$.⁸

This definition says that if an alternative does not attract an attention of the decision maker, her consideration set does not change when such an item becomes unavailable.

To illustrate that this is a normatively appealing property, we shall provide two examples where the decision maker's consideration set mapping should be an attention filter. The first example is based on unawareness. Imagine a decision maker (wrongly) believes $\Gamma(S)$ is her feasible set (S is the actual one). That is, she is not only unaware of alternatives in $S \setminus \Gamma(S)$ and but unaware that she is unaware of these alternatives. If so, she will not recognize the change of the feasible set when such an item becomes unavailable so her consideration set should not change. This is exactly what the property dictates.

The second one is choosing rationally what to consider (or not to consider). Because of scarcity of time and/or complexity of decision problems, a decision maker selectively focuses on a smaller set of alternatives and ignores the rest. Suppose she knows S is her entire feasible set. Then, she picks her consideration set $\Gamma(S)$ optimally based on her prior beliefs about the value of alternatives and the cost of inspecting them. Then, her consideration set mapping must satisfy our property. To see this, imagine that she considers only a and b when her feasible set is $\{a, b, c, d\}$ ($\Gamma(\{a, b, c, d\}) = \{a, b\}$). Assume that d becomes unavailable now. She has no reason to add c to her consideration set because she could have done so when d was available. For the same reason, it is not rational to remove b (or a) from her consideration set. Therefore, it must be $\Gamma(\{a, b, c\}) = \{a, b\}$. That is, her consideration set mapping is an attention filter. Notice that this must be true whatever beliefs and cost function she has.⁹

Furthermore, in addition to being normatively appealing, our condition is also descriptively appealing. Many heuristics that are actually used to narrow down the

⁸Throughout the paper, we write $S \setminus x$ instead of $S \setminus \{x\}$ for simplicity.

⁹The only exception is that the feasible set itself conveys some information that affects her belief or cost function.

set of choosable options generate attention filters. We list some of them.

▷ **Top N:** A decision maker considers only top N alternatives according to some criterion that is different from her preference. For instance:

- Consider only the three cheapest suppliers in the market (Uwe Dulleck, et al (2008)).
- Consider the N most advertised products in the market.
- Consider the products that appear in the first page of the websearch and/or sponsored links (Gord Hotchkiss, et al (2004)).
- Consider the first N available alternatives according to an exogenously given order (Salant and Rubinstein (2008)).¹⁰

▷ **Top on each criterion:** A decision maker has several criteria and considers only the best alternative(s) in each criterion.¹¹ For instance:

- Consider only a job candidate if she the best in a program. Or consider the top two job candidates from all first-tier schools and the top candidate from second-tier schools.
- Consider only the cheapest car, the safest car, and the most fuel efficient car in the market.

▷ **Most popular category:** A decision maker considers alternatives that belong to the most popular “category” in the market. For instance:

- There are several bike shops in the DM’s town. The DM first checks online to find the store offering the most varieties of bikes and goes to that one. Therefore,

¹⁰Salant and Rubinstein (2008) characterize this class of choice functions by assuming N is observable.

¹¹This heuristic is very close to “Rationalization” of Cherepanov, et al. (2010) indeed, it is a strict subset of Cherepanov, et al. (2010). In their model, unlike “the top on each criterion”, depending on the feasible set, different sets of criteria might be utilized to eliminate alternatives in the first stage.

the DM only considers bikes sold in the selected store.¹² Sergio Zyman (1999) provides real-world evidence for such behavior. The sale of Sprite is increased dramatically when they are simply repositioned from the category of lemon-limes (less popular category) to soda (more popular category).

2.2 Choice with Limited Attention

In the previous subsection, we define the concept of the attention filter which is both normatively and descriptively appealing. Now we define the choice behavior of a decision maker who picks the best element from her consideration set according to the complete and transitive preference. Formally, a choice function assigns a unique element to each feasible set. That is, $c : \mathcal{X} \rightarrow X$ with $c(S) \in S$ for all $S \in \mathcal{X}$.

Definition 2. *A choice function c is a **choice with limited attention (CLA)** if there exists a complete and transitive preference \succ over X and an attention filter Γ such that $c(S)$ is the \succ -best element in $\Gamma(S)$.¹³*

In the following sections, we answer the following questions under the assumption that decision maker follows a choice with limited attention but her preference and attention filter is not observable: (1) How can we identify her preference and attention filter through her choice data? (2) Which choice functions are compatible with the model of a choice with limited attention?

3 Revealed Preference and (In)Attention

In this section, we illustrate how to infer (1) the DM's preference and (2) what the DM pays (and does not pay) attention to from her observed choice that is a CLA. The standard theory concludes that x is preferred to y when x is chosen while y is available. To justify such an inference, one must implicitly assume that she has paid attention to y . Without this hidden assumption, we cannot make any inference

¹²For instance, suppose store A deals with Makers 1 and 2's bikes while store B sells bikes from Makers 2 and 3. Then, the DM compares the number of Makers 1 and 2's bikes with that of Makers 2 and 3's to choose which store to visit.

¹³That is, $c(S) \in \Gamma(S)$ and $c(S) \succ x$ for all $x \in \Gamma(S) \setminus c(S)$.

because she may prefer y but overlooks it. Therefore, eliciting the DM's preference is no longer trivial because her choice can be attributed to her preference or to her inattention.¹⁴

This observation suggests that multiple pairs of a preference and an attention filter can generate the same choice behavior. To illustrate this, consider the choice function with three elements exhibiting a cycle:

$$c(xyz) = x, \quad c(xy) = x, \quad c(yz) = y, \quad c(xz) = z.$$

One possibility is that the DM's preference is $z \succ_1 x \succ_1 y$ and she overlooks z both at $\{x, y, z\}$ and $\{y, z\}$. Another possibility is that her preference is $x \succ_2 y \succ_2 z$ and she does not pay attention to x only at $\{x, z\}$ (see Table 1 for the corresponding attention filters).

| Preference | Attention Filter | | | | |
|-------------------------|------------------|-------|------|------|------|
| | | xyz | xy | yz | xz |
| $z \succ_1 x \succ_1 y$ | Γ_1 | xy | xy | y | xz |
| $x \succ_2 y \succ_2 z$ | Γ_2 | xyz | xy | yz | z |

Table 1: Two possible representations for the cyclical choice

We cannot identify which of them is her true preference. Nevertheless, if only these two pairs represents c , we can unambiguously conclude that she prefers x to y because both of them rank x above y . For the same reason, we can infer that she pays attention to both x and y at $\{x, y, z\}$ (Table 1). This example makes it clear that we need to define the revealed preference when multiple representations are possible.

Definition 3. *Assume c is a choice by limited attention and there are k different pairs of preference and attention filter representing c , $(\Gamma_1, \succ_1), (\Gamma_2, \succ_2), \dots, (\Gamma_k, \succ_k)$. In this case,*

- *x is revealed to be preferred to y if $x \succ_i y$ for all i ,*

¹⁴In the extreme case where choice data satisfies the weak axiom of revealed preference, we have no way of knowing whether the decision maker is aware of all alternatives and maximizing a particular preference, or whether she only pays attention to the one she chooses. In the latter, her preference has no significant importance. In Section 6, we discuss the situations where one can pin down the preference even in this extreme case.

- x is revealed to attract attention at S if $\Gamma_i(S)$ includes x for all i ,
- x is revealed **not** to attract attention at S if $\Gamma_i(S)$ excludes x for all i .

This definition is very conservative: we say x is revealed to be preferred to y only when all possible representations agree on it. We do not want to make any false claims or claims that we are not sure. This conservative approach makes it possible that a social planner is always safe to follow our welfare recommendations.

If one wants to know whether x is revealed to be preferred to y , it would appear necessary to check for every (Γ_i, \succ_i) whether it represents her choice or not. However, this is not practical especially when there are many alternatives. Instead we shall now provide a handy method to obtain the revealed preference, attention and inattention completely.

In the example above, when Γ is an attention filter, it is possible to determine the relative ranking between x and y . To see this, note that if the DM pays attention to x and z at both $\{x, z\}$ and $\{x, y, z\}$, then we should not observe choice reversal. If there is a choice reversal, then this means that her attention set changes when y is removed from $\{x, y, z\}$. This is possible only when she pays attention to y at $\{x, y, z\}$ (*Revealed Attention*). Given the fact that x is chosen from $\{x, y, z\}$ we conclude that the DM prefers x over y (*Revealed Preference*). This observation can be easily generalized. Whenever the choices change as a consequence of removing an alternative, the initially chosen alternative is preferred to the removed one. Formally, for any distinct x and y , define:

$$xPy \text{ if there exists } T \text{ such that } c(T) = x \neq c(T \setminus y). \quad (1)$$

By the argument analogous to the one above, if xPy then x is revealed to be preferred to y . In addition, since the underlying preferences are transitive, we also conclude that she prefers x to z if xPy and yPz for some y , even when xPz is not directly revealed from the choice. Therefore, the transitive closure of P , denoted by P_R , must also be part of her revealed preference. One may wonder whether some revealed preference is overlooked by P_R . The next theorem states that the answer is no: P_R is the revealed preference in our model.

Theorem 1. (*Revealed Preference*) Suppose c is a CLA. Then, x is revealed to be preferred to y if and only if xP_Ry .

Theorem 1 illustrates that welfare analysis is possible even with non-standard choices. In addition, it provides a guideline for a policy maker.

The revealed preference characterized by Theorem 1 is independent of *how* her consideration set is formed, as long as her consideration set mapping is an attention filter. Therefore, it is applicable to many situations. However, depending on how her consideration set is formed, it may appear to be inappropriate to base the welfare analysis solely on our revealed preference. For instance, one can interpret her attention/inattention as some reflections of her preference and argue that it should be incorporated to the welfare analysis. We do not disagree with such attempts, but to do so the policy maker must have more concrete views about her actual consideration set formation. In those cases, our revealed preference is what the policy maker can say without knowledge of the DM's underlying consideration set formation process.

Notice that our analysis is a model-based approach as the welfare criterion is obtained assuming a particular underlying choice procedure: a choice with limited attention. On the other hand, Bernheim and Rangel (2009) propose that one should make a welfare judgement only when the choices are unambiguous. Their intuition is that if x is never chosen while y is present and y is chosen at least once when x is available, then y should be strictly welfare improving over x . Since this intuitive criterion is independent of the underlying model, their approach is called model-free. By the help of Theorem 1, we are able to illustrate in a reasonable example that the above intuition might deceive us. In the next example, while x is never chosen when y is present, y is chosen at least once over x . Nevertheless, Theorem 1 dictates that x is revealed to be preferred to y .

Example 1. *There are four products x, y, z , and t . Each of them is packed in a box. Consider a supermarket which displays these products in its two aisles according to the following rules: (i) Each aisle can carry at most two products, (ii) x and y cannot be placed into the same aisle because they are packed in big boxes, (iii) the supermarket fills the first aisle first and uses the second aisle only if it is necessary, (iv) y and z*

are put into the first aisle whenever they are available, (v) t is placed in the first aisle only after all other available items are put in an aisle and still the first aisle has a space. Consider a customer with preference $t \succ x \succ z \succ y$ (not observable) and she only visits the first aisle and picks her most preferred item displayed in that aisle.

It is easy to see that her consideration set mapping is an attention filter as the supermarket does not change its lineups in its first aisle when something in the second aisle becomes unavailable. Hence Theorem 1 is applicable.

Since x never appears in the first aisle when y is available, she never chooses x whenever y is feasible (and y is chosen when only x and y are available). Thus, the criterion by Bernheim and Rangel (2009), although it is very conservative to make a welfare statement, concludes that y is welfare improving over x , which is opposite to her true preference.

In contrast to Bernheim and Rangel (2009), our model correctly identifies her true preference between y and x by Theorem 1. To see this, suppose all of four products are available. Then, y and z are placed in the first aisle so z is chosen. When y becomes unavailable, then x is moved to the first aisle and is chosen. Furthermore, when z is also sold out, then x and t are placed in the first aisle so she picks t . In sum, her choices will be $c(xyz) = z$, $c(xzt) = x$ and $c(xt) = t$. Then, when only choice is observable our model concludes that the DM prefers z over y and x over z . Therefore, we can identify her preference between x and y correctly.

This example highlights the importance of knowledge about the underlying choice procedure when we conduct welfare analysis.¹⁵ In other words, welfare analysis is more delicate task than it looks.

Next, we investigate when we can unambiguously conclude that the DM pays (or does not pay) attention to an alternative. Consider the choice reversal above, from which we have concluded that she prefers x to y . Therefore, whenever y is chosen, she must not have paid attention to x (*revealed inattention*).

As we illustrate, we infer that x is revealed to attract attention at S whenever x is chosen from S or removing x from S causes a choice reversal. Furthermore, it is possible to reach the same conclusion even when removing x from S does not cause a

¹⁵For a detailed discussion of this subject, see Manzini and Mariotti (2009b).

choice reversal. Imagine that the DM chooses the same item, say $\alpha \neq x$, from S and T and removing x from T causes a choice reversal, so we know $x \in \Gamma(T)$ for sure. Now collect all items that belong to either S or T but not to both. Suppose all of those items are revealed to be preferred to α . Then, those items cannot be in $\Gamma(S)$ or $\Gamma(T)$. Therefore, removing those items from S or T cannot change her consideration set. Hence, we have

$$\Gamma(S) = \Gamma(S \cap T) = \Gamma(T)$$

and can conclude that x is considered at S .

The following theorem summarizes this observation and also provides the full characterization of revealed attention and inattention.

Theorem 2. (*Revealed (In)Attention*) *Suppose c is a CLA. Then,*

- (1) *x is revealed not to attract attention at S if and only if $xP_{RC}(S)$,*
- (2) *x is revealed to attract attention at S if and only if there exists T (possibly equal to S) such that:*
 - (i) *$c(T) \neq c(T \setminus x)$,*
 - (ii) *$yP_{RC}(S)$ for all $y \in S \setminus T$,*
 $zP_{RC}(T)$ for all $z \in T \setminus S$.

Theorem 2 identifies both revealed attention and inattention. This information is as important as the revealed preference. For example, if a product is not popular in a market, it is very important for a firm to know the reason, which can either be that it is not liked by consumers or that it does not attract the attentions of consumers.

4 Characterization

The two preceding theorems characterize revealed preference and revealed (in)attention. However, they are not applicable unless the observed choice behavior is a CLA. Therefore, a question to ponder is: how can we test whether a choice data is consistent

with CLA? Surprisingly, it turns out that CLA can be simply characterized by only one observable property of choice.

Before we state the property, recall the sufficient and necessary condition for observed behavior to be consistent with the preference maximization under the full attention assumption: the Weak Axiom of Revealed Preference (WARP). WARP is equivalent to stating that every set S has the “best” alternative x^* in the sense that it must be chosen from any set T whenever x^* is available and the choice from T lies in S . Formally,

WARP: For any nonempty S , there exists $x^* \in S$ such that for any T including x^* ,

$$c(T) = x^* \text{ whenever } c(T) \in S.$$

Because of the full attention assumption, being feasible is equal to attracting attention. However, this is no longer true when we allow for the possibility of limited attention. To conclude that x^* is chosen from T , we not only need to make sure that the chosen element from T is in S and x^* is available but also that x^* attracts attention. As we have discussed, we can infer this when removing x^* from T changes the DM’s choice, which is the additional requirement for x^* to be chosen from T . This discussion suggests the following axiom, which is a weakening of WARP:

WARP with Limited Attention - WARP(LA): For any nonempty S , there exists $x^* \in S$ such that, for any T including x^* ,

$$c(T) = x^* \text{ whenever } \begin{array}{l} (i) \ c(T) \in S, \text{ and} \\ (ii) \ c(T) \neq c(T \setminus x^*) \end{array}$$

WARP with Limited Attention indeed guarantees that the binary relation P defined in (1) is acyclic and it fully characterizes the class of choice functions generated by an attention filter. The next lemma makes it clear that WARP(LA) is equivalent to the fact that P has no cycle.

Lemma 1. *P is acyclic if and only if c satisfies WARP with Limited Attention.*

Proof. (The if-part) Suppose P has a cycle: $x_1 P x_2 P \cdots P x_k P x_1$. Then for each $i = 1, \dots, k - 1$ there exists T_i such that $x_i = c(T_i) \neq c(T_i \setminus x_{i+1})$ and $x_k = c(T_k) \neq$

$c(T_k \setminus x_1)$. Consider the set $\{x_1, \dots, x_k\} \equiv S$. Then, for every $x \in S$, there exists T such that $c(T) \in S$ and $c(T \setminus x) \neq c(T)$ but $x \neq c(T)$, so WARP with Limited Attention is violated.

(The only-if part) Suppose P is acyclic. Then every S has at least one element x such that there is no $y \in S$ with yPx , which means that there is no $y \in S$ with $y = c(T) \neq c(T \setminus x)$. Equivalently, whenever $c(T) \in S$ and $c(T) \neq c(T \setminus x)$, it must be $x = c(T)$, which is WARP with Limited Attention. \square

Theorem 3. (*Characterization*) c satisfies WARP with Limited Attention if and only if c is a CLA.

Theorem 3 shows that a CLA is captured by a single behavioral postulate. This makes it possible to test our model non-parametrically by using the standard revealed-preference technique à la Samuelson and to derive the decision maker's preferences and attention filter based on Theorem 1 and 2 from the observed choice data.

As we mentioned in the introduction, there are several related decision theoretic models where the final choice is made after eliminating several items, which are similar to a CLA such as Manzini and Mariotti (2007 and forthcoming), Cherepanov, et al. (2010) and Lleras, et al. (2010). We shall illustrate that our model is not only different from these model in a descriptive sense but also in a behavior sense by showing examples that can be captured by one but not by the other.

First, we shall present an example of a CLA that cannot be explained by any of these models. Although these models have different characterizations, all of them satisfy the axiom called Weak-WARP (Manzini and Mariotti (2007)) so we only need to show that it violates that axiom. The Weak-WARP states that if x is chosen over y both from the pair and from a larger set, y cannot be chosen from anywhere between. Formally,

Weak-WARP. Suppose $\{x, y\} \subset T \subset S$. If $x = c(xy) = c(S)$, then $y \neq c(T)$.

Consider the following example of a CLA:

Example 2. *There are four alternatives x, y, a, b . The alternatives a and b are never chosen (unless there is no other alternative) but they alter the attention of the decision maker. Her preference is $y \succ x \succ a \succ b$ and picks the best alternative from those she considers. She considers y only when either a or b is feasible but not both and always considers all other alternatives. It is easy to see that her consideration set mapping is an attention filter so her choice function satisfies WARP(LA). However, it does not satisfy Weak-WARP because $c(xy) = c(xyab) = x$ (y is not considered) but $c(xya) = y$.*

Conversely, none of the above alternative models is a special case of the CLA model. In Example 3, we present a model of Rational Shortlist Method of Manzini and Mariotti (2007) that cannot be a CLA. One can easily verify that the exactly same choice function can be generated by other models mentioned above. The rational shortlist model consists of two rationales P_1 and P_2 where P_1 has no cycle (not necessarily transitive) and P_2 is a complete and transitive order.¹⁶ The decision is made applying these rationales sequentially to eliminate alternatives. Consider the following example of the rational shortlist model:

Example 3. *The first rationale (not transitive¹⁷) and the second rationale (transitive) are:*

$$tP_1y, yP_1x, zP_1x, zP_1s$$

$$sP_2xP_2yP_2zP_2t$$

For instance, if the feasible set is $\{s, y, z\}$, s is eliminated in the first stage by z and she picks y in the second stage by comparing y and z according to P_2 . However, this choice function generates contradictory revealed preferences if it was a CLA:

- zPt since $z = c(yzt)$ and $y = c(yz)$,

¹⁶Actually, Manzini and Mariotti (2007) does not require the second rationale (P_2) to be complete and transitive (it only requires P_2 to be asymmetric). We put the stronger requirement on P_2 in order to highlight that the difference between these models is generated by the first stage, not by the incompleteness or intransitivity of the second rationale, which corresponds to the DM's preference in our model.

¹⁷One can show that if P_1 is transitive, the first stage elimination generates an attention filter so the resulting choice will be a CLA as long as P_2 is complete and transitive.

- tPy since $t = c(xyt)$ and $x = c(xt)$,
- yPz since $y = c(syz)$ and $s = c(sy)$.

Thus, it cannot be explained by a CLA by Lemma 1. Hence, this choice cannot be a part of our model.

5 Anomalies

Our limited attention model is capable of accommodating several frequently observed behaviors: Attraction Effect, Cyclical Choice, and Choosing Pairwisely Unchosen. Our explanations for these choice patterns solely depend on limited attention, hence seemingly irrational behaviors can be explained without introducing changing preference. We will overview them and illustrate how our model accommodates them. In addition to that, we elicit the DM's preference, attention and inattention from such choice data.

ATTRACTION EFFECT

The attraction effect refers to a phenomenon where adding an irrelevant alternative to a choice set affects the choice.¹⁸ A typical attraction effect choice patterns is

$$c(xyd) = y, \quad c(xy) = x, \quad c(yd) = y, \quad c(xd) = x.$$

Here d is the irrelevant alternative that shifts the choice from x to y . Thus, d is the decoy of y . Donald R. Lehmann and Yigang Pan (1994) experimentally show that introducing new products causes an attraction effect particularly by affecting the composition of consideration sets. How the CLA model accommodates the attraction effect is in line with their findings. One possible representation is that the DM's preference is $y \succ x \succ d$ and she considers y only when d is present (otherwise, she

¹⁸This phenomenon is well-documented and robust in behavioral research on marketing (Joel Huber, John W. Payne and Christopher Puto (1982), Amos Tversky and Itamar Simonson (1993)), including in choice among monetary gambles, political candidates, job candidates, environmental issues, and medical decision making. Advertising irrelevant alternatives is commonly used as a marketing strategy to invoke the attraction effect on the customers.

considers everything). It is clear that her consideration set mapping is an attention filter.

Now we elicit the preference of a decision maker whose choice behavior follows the same pattern above without knowing her preference and consideration sets. By Theorem 1, $y = c(xyd) \neq c(xy)$ imply that y is revealed to be preferred to d . That is, our model judges that she prefers y over its own decoy.

One can naturally imagine the attraction effect with more than one decoy. However most of the theoretical literature cannot accommodate it,¹⁹ but our model can. Consider there are two decoys d_x and d_y of x and y , respectively. That is,

$$c(xyd_xd_y) = x, \quad c(xyd_y) = y, \quad c(xy) = x.$$

The CLA model can accommodate this behavior: she considers y only when d_y is present but d_x is not. She ignores x when d_y is available but not d_x . Then she will exhibit the above choice as long as she prefers x over d_x and y over d_y .

Again, assume we have no prior information about the DM's preference and consideration sets. The first two choices reveal that she pays attention to d_x at $\{x, y, d_x, d_y\}$ so prefers x over d_x . Similarly, the second and third tell us she prefers y over d_y . Therefore, our approach again elicits her preference between an alternative and its decoy.

CYCLICAL CHOICE

Kenneth O. May (1954) provides the first experiment where cyclical choice patterns are observed and these results have been replicated in many different choice environments (e.g. Tversky (1969), Graham Loomes, Chris Starmer, and Robert Sugden (1969), Manzini and Mariotti (2009a), Michael Mandler, Manzini and Mariotti (2009)). Consider a cyclical choice pattern:

$$c(xyz) = x, \quad c(xy) = x, \quad c(yz) = y, \quad c(xz) = z.$$

We have already illustrated that this choice pattern can be captured by our model

¹⁹This generalized attraction effect is another example that lies outside of recent models provided in Cherepanov, et al. (2008), Manzini and Mariotti (forthcoming) and Lleras, et al. (2010) since it does not satisfy Weak-WARP. There are two exceptions: Efe A. Ok, Pietro Ortoleva and Gil Riella (2010) and Geoffroy de Clippel and Eliaz (2010). However, these two models can accommodate neither Cyclical nor Choosing Pairwisely choice patterns.

at the beginning of Section 3. Now let us elicit the preference. Since the DM exhibits a choice reversal when y is removed from $\{x, y, z\}$, we can identify that y attracts her attention when these three elements are present. So, we can conclude that she prefers x over y . However, as illustrated before, we cannot determine the ranking of z .

CHOOSING PAIRWISELY UNCHOSEN

In this choice pattern, the DM chooses an alternative that is never chosen from pairwise comparisons:

$$c(xyz) = z, \quad c(xy) = x, \quad c(yz) = y, \quad c(xz) = x.$$

Since removing x or y from $\{x, y, z\}$ changes her choice, it is revealed that z is better than x and y but we cannot determine her preference between x and y . Since her revealed preference has no cycle, her behavior is captured by our model through Lemma 1 and Theorem 3.

Note that the best element, z , is not chosen in any binary choice so we can conclude that she pays attention to z only when x and y are present. Applying Theorem 2, we can pin down her consideration set uniquely except when her feasible set is $\{x, y\}$:

| Revealed Preference | zP_Rx and zP_Ry | | | |
|----------------------|---------------------|------|------|------|
| | xyz | xy | yz | xz |
| Revealed Attention | xyz | x | y | x |
| Revealed Inattention | - | - | z | z |

Table 2: Choosing Pairwisely Unchosen

One possible story that generates such an attention pattern is “searching more when the decision is tough.” Several items are hard to find even if they are feasible. The decision maker first considers alternatives that are feasible and easy to find and if there is an item that dominates all others, she chooses it immediately. Otherwise, she makes an extensive search to find all feasible items. In the former case, the consideration set consists only of easily found (and feasible) alternatives and in the latter case it coincides with the feasible set. Given this story, suppose her true preference is $z \succ x \succ y$ where the decision between x and y is very tough and z is hard to find. She makes an extensive search to find z only if she sees both x and y . If either x or y is missing, she does not bother to search, and therefore overlooks z .

6 Further Comments

In this section, we discuss the boundaries of our method. First of all, our revealed preference could be very incomplete, in other words, it only provides coarse welfare judgements. In the extreme case where the choice data satisfies WARP, Theorem 1 and Theorem 2 do not provide any identification of the preference and attention/inattention. This is because the DM's behavior can be attributed fully to her preference or to her inattention (always considering her actual choice). Thus, we cannot make any statement without imposing any additional assumption. This extreme example illustrates the limitation of choice data, which alone is not enough to identify her preferences. Notice that the classical revealed preference is not an exception since it implicitly assumes the full attention.

Nevertheless, a policy maker may be *forced* to make a welfare judgement even when our revealed preference is silent. There are three directions to deal with incompleteness of our revealed preference: (1) looking for additional data other than choice data, (2) imposing additional structures on attention filter, and/or (3) utilizing other methods as long as the resulting revealed preference includes ours. We will discuss each of them in detail.

◇ Additional Data: The idea of our (direct) revealed preference is that we can conclude x is preferred to y if x is chosen while y gets an attention, which is inferred when removing y changes her choice. However, if we know y is considered for some other reason, we will naturally make the same conclusion even without observing such a choice change. One can get such an information from many sources such as eye-tracking, fMRI and the tracking system in the internet commerce.²⁰ If the policy maker believes that these sources are trustable, he can utilize them to get extra revealed preferences. We now illustrate how it can be combined with our revealed preference.

Assume a policy maker has an extra piece of information about consumer's preference. For instance, the choice data may not reveal her ranking between x and y but some laboratory experiment or survey study may have already found that she

²⁰In this regard, our theory highlights the importance of other tools (besides the observed choices) which can shed light on the choice process rather than outcome.

prefers x over y . In such a case, the policy maker can add $x \succ y$ to the revealed preference generated by our method (Theorem 1), say $P' = P_R \cup \{(x, y)\}$. By using the transitive closure of P' , denoted by P'_R , the policy maker can obtain more attention/inattention information like Theorem 2. Indeed, Theorem 1 and 2 are exactly applicable by replacing P_R with the transitive closure of P'_R .

Similarly, a policy maker may know she pays attention to x under certain decision problem. This information immediately generates more information about her preference, (the chosen element here is better than x), which tells more about her attention/inattention like in the previous case.

◇ Further Restrictions on Consideration Sets: The other direction is to impose additional restrictions on Γ other than being an attention filter. For example, if the source of limited attention is simply the abundance of alternatives, one reasonable restriction is that the decision maker considers at least two alternatives for each decision problem as a benchmark. That is $|\Gamma(S)| \geq 2$. Under this restriction, the choice data reveals her preference completely. This result is trivial but still it is important for a marketer to find whether an unchosen alternative attracts attention. Our approach will provide an answer for the revealed attention. The revealed attention and inattention will be characterized by Theorem 2 by replacing P_R with the completely identified preference.

Notice that the classical revealed preference can be seen as one of such an attempt with the strongest assumption on the consideration set $\Gamma(S) = S$. Our model highlights that we need to assume *how* choices are made in order to make a meaningful revealed preference exercise. The assumption about *what* are chosen (like WARP) is not enough.

◇ Other Methods: One can combine our methodology with others which try to make the welfare analysis without relying on a particular choice procedure, such as Apestegua and Ballester (2010) and Bernheim and Rangel (2009). What is common between our model and theirs is that all try to respect consumer's choice for the welfare judgment as much as possible. The difference is that our model does so only when the consumer actually considers other unchosen alternatives.

Now imagine that a policy maker knows/believes a consumer behaves according to

our model. Then, he should first elicit her preference based on our method. Admittedly, it only provides an incomplete ranking (and empty if the choice data satisfies WARP). If the policy maker is *forced* to make a complete welfare judgement with a risk of making mistakes, he can apply the other methods with the constraint of respecting the revealed preference generated by our model. In other words, these methods should be used only to break the incompleteness of our revealed preference.

For instance, consider Apestegua and Ballester’s approach. They first axiomatically construct an index to measure the consistency between choice data and a certain preference, and of all complete and transitive preferences pick the one that minimizes the inconsistency for the welfare analysis. However, if the policy maker knows the decision maker follows a choice with limited attention, he should first elicit her preference based on our method and then pick the inconsistency-minimizing preference *only from those that are consistent with our revealed preference*. The resulting welfare judgment can be wrong (can be different from her actual preference). Nevertheless, this sequential process eliminates certain mistakes the policy maker would make if he simply applied the other model-free methods. For instance, applying Apestegua and Ballester’s approach directly to Example 1 will lead the wrong conclusion: y is welfare improving over x but this sequential advocacy certainly kills such a mistake.

7 Concluding Remarks

Limited attention has been widely studied in economics: neglecting the nontransparent taxes (Raj Chetty, Adam Looney, and Kory Kroft (2009)), inattention to released information (Stefano DellaVigna and Joshua Pollet (2007)), costly information acquisition (Xavier Gabaix, et al. (2006)), and rational inattention in macroeconomics (Christopher A. Sims (2003)). For example, Goeree (2008) shows that relaxing the full attention assumption by allowing customers to be unaware of some computers in the market is enough to explain the high markups in the PC industry.

In this paper, we study the implications of limited attention on revealed preference. We illustrate when and how one can deduce both the preference and consideration sets of a DM who follows a CLA. The distinction between a preference and an (in)attention is crucial. For instance, if a product is not popular in a market, it is very important

for a firm to know the reason, which can either be that it is not liked by consumers or that it does not attract the attentions of consumers. Our model provides a theoretical framework to distinguish these two possibilities. Similarly, a social planner can find a proper strategy to make sure that people choose the right option in 401(K) plans and health insurance. Hence, in a welfare analysis it is important to understand the underlying model of the DM.

Since revealed preference and (in)attention are the main focus of the paper, we impose a rather weak restriction on consideration sets. Such a weak condition allows us to apply our revealed preference and (in)attention theorems to seemingly irrational choice patterns (i.e. Attraction Effect, Cyclical Choice, and Choosing Pairwisely Unchosen). Nevertheless, depending on the intended application, our framework can be used to analyze choices under different restrictions on consideration sets.

◇ In many real-world markets, products compete with each other for the space in the consideration set of the DM, who has cognitive limitations. In these situations, if an alternative attracts attention when there exist many others, then it is easier to be considered when some of other alternatives become unavailable. If a product is able to attract attention in a crowded supermarket shelf, the same product will be noticed when there are fewer alternatives, i.e., $x \in \Gamma(T)$ implies $x \in \Gamma(S)$ whenever $x \in S \subset T$. Lleras, et al. (2010) extensively study consideration sets which satisfy this property. They also consider the cases where both conditions are satisfied.

◇ Lleras, et al. (2010) also consider another special case whereby the decision maker overlooks or disregards an alternative because it is dominated by another item in some aspect. Imagine Maryland's economics department is hiring one tenure-track theorist. Since there are too many candidates in the job market to consider all of them, the department asks other departments to recommend their best theory student. Therefore, a candidate from Michigan is ignored if and only if there is another Michigan candidate who is rated better by Michigan. In this case, Maryland's filter is represented by a irreflexive and transitive order as long as each department's ranking over its students is rational. Formally, given an irreflexive and transitive (possible incomplete) order \triangleright , the attention filter consists of alternatives which are undominated with respect to this order, $\Gamma_{\triangleright}(S) = \{x \in S \mid \nexists y \in S \text{ s.t. } y \triangleright x\}$.

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9 Appendix

The Proofs of Theorem 1, Theorem 2 and Theorem 3

Notice that the if-parts of Theorem 1 and Theorem 2 have been already shown in the main text. The following proofs use these results.

Proof of Theorem 3

Suppose c is a CLA represented by (\succ, Γ) . Then Theorem 1(if part) implies that \succ must include P so P must be acyclic. Therefore, by Lemma 1, c must satisfy WARP(LA).

Now suppose that c satisfies WARP(LA). By Lemma 1, P is acyclic so there is a preference \succ that includes P . Pick any such preference arbitrarily and define

$$\Gamma(S) = \{x \in S : c(S) \succ x\} \cup \{c(S)\} \quad (2)$$

Then, it is clear that $c(S)$ is the unique \succ -best element in $\Gamma(S)$ so all we need to show is that Γ is an attention filter. Suppose $x \in S$ but $x \notin \Gamma(S)$ (so $x \neq c(S)$). By construction, $x \succ c(S)$ so it cannot be $c(S)Px$. Hence, it must be $c(S) = c(S \setminus x)$ so we have $\Gamma(S) = \Gamma(S \setminus x)$. \square

Proof of Theorem 1 (The Only-If part)

Suppose xP_Ry does not hold. Then there exists a preference that includes P_R and ranks y better than x . The proof of Theorem 3 shows that c can be represented by such a preference so x is not revealed to be preferred to y . \square

Proof of Theorem 2 (The Only-If parts)

(Revealed Inattention) Suppose x is not revealed to be preferred to $c(S)$. Then pick a preference that includes P_R and puts $c(S)$ above x . The proof of Theorem 3 shows that c can be represented by such a preference and an attention filter Γ with $x \in \Gamma(S)$.

(Revealed Attention) Suppose there exists no T which satisfies the condition. We shall prove that if c is a CLA then it can be represented by some attention filter Γ with $x \notin \Gamma(S)$. If $c(S)P_Rx$ does not hold, we have already shown that c can be represented with $x \succ c(S)$ and $x \notin \Gamma(S)$ so x is not revealed to attract attention at S , so we focus on the case when $c(S)\tilde{P}_R x$.

Now construct a binary relation, \tilde{P} , where $a\tilde{P}b$ if and only if “ aP_Rb ” or “ $a = c(S)$ and not $bP_Rc(S)$.” That is, \tilde{P} puts $c(S)$ as high as possible as long as it does not contradict P_R . Since P_R is acyclic and c is represented by an attention filter, one can show that \tilde{P} is also acyclic. Given this, take any preference relation \succ that includes

\tilde{P} , which includes P_R as well. We have already shown that $\tilde{\Gamma}(S) \equiv \{z \in S : c(S) \succ z\} \cup \{c(S)\}$ is an attention filter and $(\tilde{\Gamma}, \succ)$ represents c . Now define Γ as follows :

$$\Gamma(S') = \begin{cases} \tilde{\Gamma}(S') & \text{for } S' \notin \mathcal{D} \\ \tilde{\Gamma}(S') \setminus x & \text{for } S' \in \mathcal{D} \end{cases}$$

where \mathcal{D} is a collections of sets such that

$$\mathcal{D} = \left\{ S' \subset X : \begin{array}{l} c(S') = c(S) \\ z P_R c(S) \text{ for all } z \in (S \setminus S') \cup (S' \setminus S) \end{array} \text{ and } \right\}$$

That is, Γ is obtained from $\tilde{\Gamma}$ by removing from x any budget set S' where $c(S) = c(S')$ and any item that belongs to S or S' but not to both is revealed to be better than $c(S)$. Notice that x cannot be $c(S)$ because if this true, the condition of the statement is satisfied for $T = S$. Hence, $\Gamma(S') \subset \tilde{\Gamma}(S')$ always includes $c(S')$. Furthermore the proof of Theorem 3 shows that $(\tilde{\Gamma}, \succ)$ represents c . Therefore, (Γ, \succ) also represents c so we only need to show that Γ is an attention filter.

To do that, it is useful to notice that $\tilde{\Gamma}$ is an attention filter and $c(T') = c(T'')$ whenever $\tilde{\Gamma}(T') = \tilde{\Gamma}(T'')$ because $(\tilde{\Gamma}, \succ)$ represents c .

Suppose $y \notin \Gamma(T)$. We shall prove $\Gamma(T) = \Gamma(T \setminus y)$.

Case I: $y = x$

If $T \notin \mathcal{D}$, then we have $\Gamma(T) = \tilde{\Gamma}(T) = \tilde{\Gamma}(T \setminus x) = \Gamma(T \setminus x)$. If $T \in \mathcal{D}$, then it must be $c(T) = c(T \setminus x)$ (otherwise, the condition of the statement is satisfied) so by construction of $\tilde{\Gamma}$ and Γ , we have $\Gamma(T) = \tilde{\Gamma}(T) \setminus x = \tilde{\Gamma}(T \setminus x) = \Gamma(T \setminus x)$.

Case II: $T \in \mathcal{D}$ and $y \neq x$

Since $y \notin \Gamma(T)$ is equivalent to $y \notin \tilde{\Gamma}(T)$, we have $\tilde{\Gamma}(T) = \tilde{\Gamma}(T \setminus y)$. Therefore, $c(T \setminus y) = c(T) = c(S)$. By construction of Γ and $\tilde{\Gamma}$, it must be $y \succ c(S)$, which implies $y P_R c(S)$ by construction of \succ . Therefore, $T \setminus y \in \mathcal{D}$. Therefore, $\Gamma(T) = \tilde{\Gamma}(T) \setminus x = \tilde{\Gamma}(T \setminus y) \setminus x = \Gamma(T \setminus y)$.

Case III: $T \notin \mathcal{D}$ and $y \neq x$

If $T \setminus y \in \mathcal{D}$, analogously to the previous case, we have $c(T) = c(T \setminus y) = c(S)$ and $y P_R c(S)$ so it must be $T \in \mathcal{D}$, which is a contradiction. Hence, $T \setminus y \notin \mathcal{D}$ so we have $\Gamma(T) = \tilde{\Gamma}(T) = \tilde{\Gamma}(T \setminus y) = \Gamma(T \setminus y)$. \square