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Attraction comes from many sources: Attentional and comparative processes in decoy effects

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Abstract

The attraction effect emerges when adding a seemingly irrelevant option (decoy) to a binary choice shifts preference towards a target option. This suggests that choice behaviour is dynamic, i.e., choice values are developed during deliberation, rather than manifesting some pre-existing preference set. Whereas several models of multialternative and multiattribute decision making consider dynamic choice processes as crucial to explain the attraction effect, empirically investigating the exact nature of such processes requires complementing choice output with other data. In this study, we focused on asymmetrically dominated decoys (i.e., decoys that are clearly dominated only by the target option) to examine the attentional and comparative processes responsible for the attraction effect. Through an eye-tracker paradigm, we showed that the decoy option can affect subjects' preferences in two different and not mutually exclusive ways: by focusing the attention on the salient option and the dominance attribute, and by increasing comparisons with the choice dominant pattern. Although conceptually and procedurally distinct, both pathways for decoy effects produce an increase in preferences for the target option, in line with attentional and dynamic models of decision making. Eye-tracking data provide further details to the verification of such models, by highlighting the context-dependent nature of attention and the development of similarity-driven competitive decisional processes.

Keywords: attraction effect, decoy effect, context effects, attention, decision making, eye-tracking

1 Introduction

The attraction effect (decoy effect or asymmetric dominance effect) is one of the clearest examples of how human choice is affected by contextual features (Huber, Payne & Puto, 1982; Huber & Puto, 1983). It shows that, during a choice, the decision maker is highly sensitive to the options' architecture, and it suggests that format, presentation order, similarity and salience of the options can affect preferences (for a review, see Frederick, Lee & Baskin, 2014). It has been repeatedly shown that decision makers are systematically influenced by the context in which the choice is made, and options' subjective values are affected by the quality and quantity of other available alternatives (Gluth, Hotaling & Rieskamp, 2017). These biases are clear evidence that, against the classical economic theories' prescriptions (von Neumann & Morgenstern, 1947; Luce, 1959), adding irrelevant alternatives can affect the decision maker's behaviour by eliciting a preference reversal effect (Cataldo & Cohen, 2018).

In the last decades, scholars have outlined three main types of context effects: the attraction effect (Huber et al., 1982), the compromise effect (Simonson, 1989), and the similarity effect (Tversky, 1972). In the attraction effect, i.e., asymmetric dominance effect (ADE, from now on), the role of the decoy (i.e., the new, apparently irrelevant and non-preferred option) is to strengthen the preference for one of the options (the target of the decoy) to the detriment of the other main alternative (the competitor). A precondition of the ADE elicitation is the multi-attribute structure of the available options: each alternative has to present at least two attribute dimensions.

In a ternary choice set, an asymmetrically dominated decoy is typically built to be clearly inferior to the target option in one attribute dimension, while being equally rewarding on the other relevant feature. Additionally, it must be totally different from the competitor alternative on both dimensions. The similarity and the proximity in the attribute space between the dominant (target) and the dominated (AD decoy) options make the former more attractive and desirable for the decision makers. For an illustration of ADE, let us consider the following example of a house rental. The tenant has to choose between two houses based on two attribute dimensions: the proximity to the city centre and the economic value. House A, the best one on the distance dimension, is located a 10-minute walk from the city centre and has a cost

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of $120 per day. House B is a 40-minute walk from the city centre and has a price of $60 per day, which makes it more advantageous on the economic attribute. The tenant's choice can be affected by the addition of a new option asymmetrically dominated by another one. For instance, consider a house that is again 10 minutes from the city centre, but it has a cost of $135 per night. In this case, the introduction of this option, which is dominated by house A on the cost dimension, produces a preference shift toward A, the target, for its being more advantageous and similar to the decoy as compared to the competitor. Similarly, a compromise decoy (C) is designed to make the target option a middle ground among alternatives. Since decision makers tend to avoid extreme options, C elicits a compromise effect which produces an increase in the target preferences (Simonson, 1989). Lastly, a new option that is similar and competitive to a pre-existing one reduces the choice possibility of the directly competing option (Tversky, 1972).

To date, ADE has been demonstrated in many behavioural and research areas such as consumer choices (Huber et al., 1982; Huber & Puto, 1983; Heath & Chatterjee, 1995, Frederick et al., 2014), political decision (Herne, 1997), evaluation procedures (Slaughter, Sinar & Highhouse, 1999), gambling (Huber et al., 1982, Cheng et al., 2012), physician decision making (Schwartz & Chapman, 1999), dating (Ariely, 2009), legal decision making (Kelman, et al., 1996) and episodic memory judgments (Maylor & Roberts, 2007). However, despite ADE seems to be well established both with numerical stimulus (Frederick et al., 2014; Huber & Puto, 1983; Huber et al., 1982; Simonson, 1989) and perceptual attributes (Trueblood, Brown & Heathcote, 2013; Trueblood & Pettibone, 2017), its effectiveness outside of strict research paradigms has been questioned (Frederick et al. 2014; Yang and Lynn 2014). More recently, Huber end colleagues (2014) drew up a list of detailed criteria to be met in order to elicit ADE, such as a clear dominance relation or weak baseline preferences, and some studies tested the possibility of using ADE as a nudge or correction tool for undesirable behaviours (Li, Sun & Chen, 2019; Marini & Paglieri, 2019).

However, although ADE and other contexts effects are well documented in a wide range of decisional domains, less is known about the cognitive mechanisms and attentional processes that lead to the elicitation of these effects. Many recent economic and psychological models agree that context-dependent choice shifts in multialternative decision making arise from the recruitment of cognitive mechanisms that go beyond mere expected utility calculation (value maximising models; Busemeyer & Townsend, 1993; Roe, Busemeyer & Townsend, 2001; Brown & Heatcote 2008; Hotaling, Busemeyer & Li, 2010; Usher & McClelland, 2004; Trueblood et al., 2014). For these reasons, new decision models are accounting and explaining context effects in choice situations as dynamic processes that evolves over time (Turner et al., 2018).

Multialternative decision field theory (MDFT; Roe et al., 2001; Hotaling et al., 2010) seems to be the model that better accounts for the ADE phenomenon (for comparison with other models, see Turner et al., 2018). MDFT, based on decision field theory (DFT; Busemeyer & Townsend, 1993), describes preferences in terms of dynamic processes that evolve during deliberation time. The decisional process is characterized by a gradual accumulation of evidence for different options, until the preference state for one alternative reaches a sort of threshold, turning into choice (see also Diederich & Trueblood, 2018). During the whole process, each option is linked to a valence that exemplifies the momentary possibility of a specific option of being chosen. Importantly, valences are the result of comparative processes among available and pre-weighted alternatives. These comparative processes are the root cause of the ADE elicitation. The clear dominance relation between target and decoy results in a negative preference state for the decoy. Subsequently, the negative activation previously assigned to the unattractive dominated alternative elicits a boosting effect for the best close option (the target) in a similarity-driven competitive process (Roe et al., 2001; Hotaling et al., 2010).

The present study aims to further investigate the comparative process and the attentional mechanisms that affect (and reflect) comparisons and, in a broad sense, choice behaviour. Since the comparative process is the only plausible reason why the addition of a non-chosen alternative can manipulate decision makers' preferences (Simonson et al., 2013), it is crucial to determine how comparisons affect the subjective value attribution. For these reasons, we wanted to directly test the role of the decoy in boosting target preferences by examining the comparisons pattern among options (target-decoy and competitor-decoy) and the shifts in attention elicited by the decoy (fixation time on the target option and the dominance attribute).

Recently, some scholars outlined different models of how, in a multiattribute environment, comparisons are allocated among alternatives (Dai & Busemeyer, 2014; Noguchi & Stewart, 2014; Cheng & González-Vallejo, 2016). In accounting for ADE, MDFT assumes an attribute-wise comparison model in which only one attribute is processed at a time and alternatives are repeatedly compared on such value. However, another possibility is that options are individually evaluated and attributes are merged in a new subjective integrated value, which is subsequently compared with the results of the integration of other alternatives (alternative-wise models; Scholten & Read, 2010; in intertemporal choice, Dai & Busemeyer, 2014). Recently, an eye-tracking study by Noguchi & Stewart (2014) confirmed an attribute-wise decisional approach as highlighted by a greater number of direct comparisons between attributes of different options (see also the multiattribute linear ballistic accumulator model

[MLBA], Trueblood et al., 2014). However, since many recent models postulate and assign a crucial role to the comparative process (Roe et al., 2001; Usher & McClelland, 2004; Bhatia, 2013; Wollschläger & Diederich, 2012; Trueblood et al., 2014;), we wanted to investigate the function and the development of the information acquisition process and, according to MDFT, we investigated how the comparative process (through options' revisits) both affects the choice and is affected by the decoy presence.

During decision making, it is well known that strategies of selection and sample of values affect and guide the choice process (Russo & Leclerc, 1994; Shimojo et al., 2003; Glaholt & Reingold, 2009; Krajbich, Armel & Rangel, 2010; Hills & Hertwig, 2010; Krajbich & Rangel, 2011; Noguchi & Stewart, 2014). Moreover, these studies assumed that the final choice is the result of a sequential three-phase process. After completing a preliminary inspection, decision makers start to weigh and compare options and values. This second stage, which takes most of the pre-decisional process, precedes a final validation phase. Since the second part of the process is considered the key moment of the decision (Russo & Leclerc 1994; Noguchi & Stewart, 2014; Tsuzuki et al., 2019), in this study we will analyse how comparisons are conducted and, most importantly, the role of the decoy in affecting the comparative process.

Recent studies have shown that attentional shifts, which are essential for comparisons, are good predictors of choice, and thus they can shed light on some cognitive decisional mechanisms (Orquin & Mueller Loose, 2013; Mullett & Stewart, 2016); moreover, similar and closely associated values attract the decision maker's attention to a greater extent than unrelated options (Noguchi & Stewart, 2018). Given that the decoy could both modify the salience of a choice alternative as a whole (e.g., focusing on the target option) and direct attention towards specific values (e.g., focusing on the attribute that makes the target superior to the decoy), a fine-grained investigation of its attentional influence on the decision-making process becomes relevant. A recent study by Król & Król (2019), one of the first using the eye-tracker methodology for decoy effects, found that subjects attention was mainly driven by the inferiority of the decoy rather than by its similarity to the target option. However, it remains to be understood whether the behavioural bias is due to an unbalanced weighting of the information as a result of its altered salience (Dimara et al., 2018) and/or to a hetero-direct attentional process (Trueblood & Dasari, 2017).

A previous study by Noguchi and Stewart (2014) found that, in the ADE elicitation, decision makers compare alternatives in pairs, one attribute at a time. Yet, the process triggered by the decoy, and its specific role in manipulating the attentional shift, are still unclear. For this reason, in this study we wanted to provide clear evidence on the direct role of decoy-induced attentional shifts in determining choice. Even if the latest models assign an important role to the comparative process and the attentional shifts (Roe et al., 2001; Trueblood et al., 2014), we have little or no evidence on how the attentional process is manipulated by contextual components, although many clear links between visual attention and the decision making processes have already been highlighted (Shimojo et al., 2003; Armel et al., 2008; Bird et al., 2012; Kim et al., 2012; Mitsuda & Glaholt, 2014; Noguchi & Stewart, 2014).

For all these reasons, we implemented an eye-tracker task in a multialternative and multiattribute environment aimed at eliciting ADE in intertemporal choices, in order to investigate the role of the decoy, variation in the allocation of attention and the predictive power of gaze, fixations and attentional shifts. As explained above, these dynamic processes evolve in the crucial phase of choice behaviour, thus a more fine-grained understanding of them is likely to shed further light on the underlying mechanisms of the attraction effect.

2 Methods

2.1 Subjects

A sample of 52 subjects (F=31, right-handed=42) was recruited for this study: all subjects were Italian native speakers between 20 and 38 years old; 48% were students, 15% workers, and 37% carried out both activities. Each subject was paid a 2 € show up fee for participating in the study. Moreover, subjects were informed that one of their choices would have been randomly selected and they would have proportionately obtained the reward chosen in that specific instance; when a delayed reward was drawn, subjects would receive it after the corresponding delay. This methodology made sure subjects were incentivized to answer as closely to their internal preferences as possible, thus providing a solution to a common concern in decision making studies. Indeed, in regards to ADE, some recent studies have questioned the possibility of observing the effect using real choice paradigms. The reason for this skepticism is that the vast majority of ADE studies were performed using abstract settings and hypothetical choices (for a review, see Lichters, Sarstedt & Vogt, 2015), whereas recent findings showed significant cognitive and behavioural differences in real vs. hypothetical choices (Camerer & Mobbs, 2017). Our study overcomes these problems by testing the ADE effect on choices with real consequences. Two subjects were excluded from data analysis, since the eye-tracker failed to record their gaze during the task. All 50 remaining subjects (40% male and 60% female) successfully completed the task. Informed consent was collected from all subjects before starting data collection: subjects were informed in advance about the study and the experimental protocol complied with all current ethical guidelines for behavioural research.

2.2 Design and procedure

This experiment was run on iMotions, an IT software designed to integrate behavioural outcome and biosensors data: the study consisted of a single session that lasted from 15 to 30 minutes. Firstly, subjects provided their basic demographic information. Successively, they ran the eye tracker calibration, read the main instructions and completed a task-familiarization session. Subsequently, the experiment began. Subjects completed 65 intertemporal choices (30 binaries, 30 ternaries, 5 controls) between a sooner and smaller (immediate) option (SS) or a larger and later reward (LL) – plus a decoy, in ternary choices (left panel of Figure 1). Choices were grouped into 5 blocks of 13 items each. Each block presented 6 binary choices (one for each delay and one for each magnitude randomly selected) and 6 ternary trade-offs (one for each delay and one for each magnitude randomly selected) plus one control question. The blocks' presentation order was completely randomized. Each choice was presented on a separate page and subjects were asked to answer using the keyboard (A key for the left position option, S for the central option and D key for the right position option): the right-centre-left placement of the options was counterbalanced across trials. Moreover, at the end of each block, subjects completed a portion of the BIS-11 (Barratt Impulsiveness Scale) of 30 standard non-randomized items (Patton et al., 1995), which acted as distractors. Throughout the experiment, we used the Tobii Pro X3-120 screen-based eye tracker recording subjects' eye-movements at 120 Hz. Each subject sat at a distance of approximately 50-60 cm from the screen and before the beginning of each block (every 13 choices during the task), the eye-tracker was automatically re-calibrated through a fixation point.

All subjects performed all the choices. For ease of reference, we will divide items into four blocks (see Appendix for the list of stimuli):

- Binary immediate choices (BI): 15 trade-offs between a sooner and smaller (SS) option and a larger and later outcome (LL) (upper panel of Table 1).
- Binary delayed choices (BD): 15 different trade-offs between a sooner and smaller (SS) option and a larger and later outcome (LL) (upper panel of Table 2). The distinction between these two blocks hinges only on the fact that BI items were later used to create ternary choices with decoys targeting SS, whereas BD items were used to construct ternary choices with decoys targeting LL: other than that, the items in these two binary blocks were designed to be analogous on all other relevant dimensions (magnitude ranges and delay lengths).
- Ternary immediate choices, i.e., choices with decoys targeting SS (TI): 15 trade-offs between a sooner and smaller (SS) and a larger and later outcome (LL) (the same ones as in the corresponding items of the binary BI), plus an asymmetrically decoy dominated by the SS alternative - (bottom panel of Table 1).
- Ternary delayed choices, i.e., choices with decoys targeting LL (TD): 15 trade-offs between a sooner and smaller (SS) and a larger and later outcome (LL) (the same ones as in the corresponding items of the binary BD), plus an asymmetrically decoy dominated by the LL alternative (see bottom panel of Table 2).

2.3 Materials

The intertemporal binary items were built for five magnitude ranges of the delayed option (tiny €10-11, small €80-88, medium €160-176, large €320-352, huge €640-704) and three lengths of delay (short 2 weeks, average 6 weeks, long 18 weeks). Every delay was framed in calendar unit (weeks): e.g., "Would you prefer to receive €50 today or €100 in 18 weeks?".

Consistently with previous studies, immediate amounts were calculated hypothesising an average discount rate of 0.017 (constant k; Kirby, 1999). This discount rate, given amount value and the reward delay of LL, was used to calculate SS amount according to Mazur's hyperbolic function (Mazur, 1987), in order to elicit time preferences sufficiently close to the presumed subjects' indifference point.

All the 30 binary items (BI & BD) were reused (in groups of 15) in the ternary condition adding an asymmetrically dominated decoy to the original binary set: in half of the trials we added a decoy dominated by the Immediate option (TI), while in the other half of the choices the decoy targeted the delayed alternative (TD). Decoy options were built by subtracting 10% from each dominating amount value (e.g., "Would you prefer to receive €93 today, €84 today or €160 in 6 weeks?").

For each item, we defined various focused Areas of Interest (AoIs). AoIs are user-defined portion of a displayed item (right panel of Figure 1). The eye tracker recorded gaze time (the total amount of time in which the subject's gaze was directed within the AoI), fixation time (the effective time spent visually exploring the AoI, using 100 ms as the cut-off to define fixation), number of revisits (the number of times a subject fixed an option), and time to first fixation (the amount of time it takes a subject to examine a certain AoI from stimulus onset) for each AoI. Moreover, when several gaze points are close in time and space, the eye tracker highlights the pattern as a fixation, a period in which our attention is fixed toward a specific portion of the stimulus. In our experiment, the minimum time for denoting a fixation was 100 milliseconds.

2.4 Hypotheses

Our paradigm was constructed to verify several interconnected hypotheses.

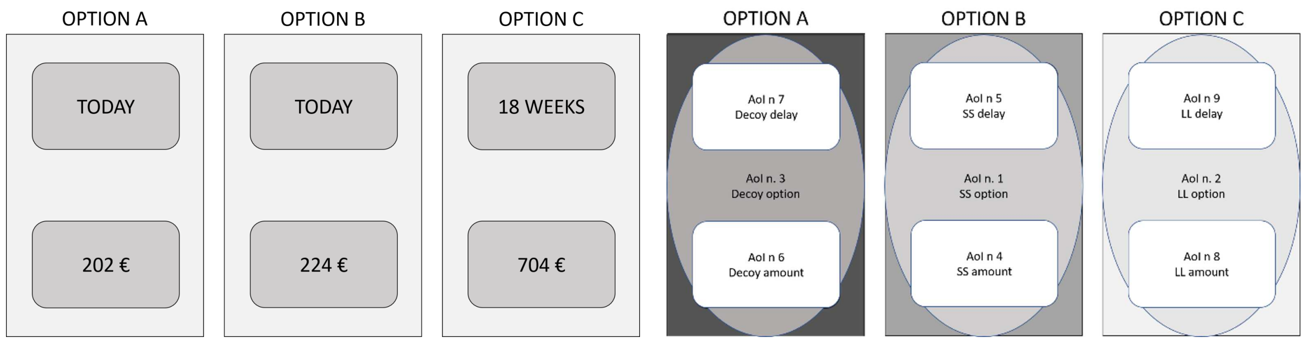

FIGURE 1: Items and AoI: Left panel: All subjects made binary and ternary intertemporal choices. Both right-left option position and up-down values were counterbalanced. Right panel: Main AoIs illustration within choices, both for values and for full options.

2.4.1 Behavioural hypotheses

Attraction effect: as regards ADE elicitation, we expected an increase in delayed preferences in the ternary condition when the decoy targeted the larger and later option (TD) compared to the opposite TI condition and the binary baseline (BD) (Kowal & Faulkner, 2016). While the effectiveness of LL-targeting decoys is well-documented in the literature on intertemporal choice, results on SS-targeting decoys are more mixed: previous studies found asymmetric decoys to be effective only when targeting the delayed option (Kowal & Faulkner, 2016; Marini & Paglieri, 2019, study 1), unless the sooner reward was presented as non-immediate – in which case the ADE would be observed also for decoys targeting the sooner option (Gluth et al., 2017; Marini & Paglieri, 2019, study 2). Marini and Paglieri (2019) suggested that this may depend on the heuristic nature of a preference for an immediate reward (the so called immediacy effect; see Keren & Roelofsma, 1995; O'Donoghue & Rabin, 1999; Benhabib et al., 2010; Andreoni & Sprenger, 2012): when an immediate option is offered, a preference for it is formed via simple heuristic processes and not running any comparison, hence decoys targeting that option ends up being ineffective. To overcome this problem, in this study stimuli presentation was explicitly designed to facilitate the comparative process responsible for decoy effects: our choice format provided options attributes on-screen at the same distance from each other (rather than a simple string of text), favouring as much as possible their comparison (both within and across alternatives; left panel of Figure 1). We speculated that, by increasing the likelihood of "paired" comparisons, we would be able to overcome the immediacy bias and thus elicit a decoy effect also towards immediate outcomes. This would allow us to observe (to the best of our knowledge, for the first time in the literature) a significant effect of SS-targeting decoys even in choices offering immediate rewards, plus the usual effect of LL-targeting decoys.

H1: Asymmetric dominance effect elicitation in the ternary conditions; that is, AD decoy addition produces an increase in the target preferences.

Response times (RTs): Consistently with the literature, we predicted longer RTs in the ternary condition compared to the binary one. Furthermore, we expected a longer deliberative process in the block with the highest ADE. Indeed, previous studies found evidence that ADE elicitation is affected by a longer deliberation time (Simonson, 1989; Wedell, 1991) and, more recently, time pressure condition has been noticed to reduce attraction effects (Pettibone, 2012; Marini & Paglieri, 2019). Moreover, various models of decision making postulate a theoretical link between choice's features and response times (Busemeyer & Townsend, 1992, 1993; Roe et al., 2001; Fehr & Rangel, 2011; Krajbich et al., 2010, 2012; Krajbich & Rangel, 2011; Trueblood et al., 2014). Lastly, we expected different RTs depending on which option is selected in the intertemporal choice. Indeed, previous studies associate a longer deliberative process with the inhibition of the immediacy heuristic, which should result in longer RT for choices favouring the delayed outcome (Berns et al., 2007, Paglieri et al., 2013; Marzilli et al., 2015).

H2: ADE elicitation, being based on a succession of systematic comparisons, results in longer response times: thus RTs should be affected by presence and strength of the effect.

H2B: LL preferences need a longer deliberative process, resulting in longer RTs.

Magnitude effect: Consistently with several previous studies on intertemporal choice (Green and Myerson, 2004; Estle et al., 2006; McKerchar & Renda, 2012; Weatherly & Terrell, 2014), we predicted a higher number of Larger and Later choices when larger amounts are at stake. Moreover, assuming the switch towards more preferences for the delayed option entails a more careful deliberation process, we hypothesized a positive correlation between magnitude and RTs.

H3: The choice magnitude affects both delay discounting and response times.

2.4.2 Eye-tracking hypotheses

Fixation times: According to an attentional hypothesis of the decoy role, we predicted that the decoy addition would shift the attentional focus on the target option. Since MDFT postulated a similarity-driven competitive process, we hypothesized that decoys would produce an increase in the target salience making it more attractive (Roe et al., 2001). This dissociation in fixation time was supposed to be elicited both between the ternary conditions with opposing decoys (TI and TD), and between each ternary condition and its corresponding baseline (BI and BD, respectively). Moreover, the realization that decoy and target are identical in terms of delay may lead subjects to focus their attention primarily on the attribute that allows discrimination between them, i.e., amount (dominance attribute): thus we hypothesized that decoys would produce a higher percentage of fixations focused on the dominance attribute in ternary conditions, compared to binary conditions.

H4: The AD decoy presence makes its target more salient; thus an option should have longer fixation times when it plays the target role.

H5: The AD decoy makes the dominance attribute more relevant; thus that attribute will be fixated more in ternary contexts, in relation to the other one.

Revisits number: Another hypothesis of the decoy role was about its comparative power. Indeed, we predicted that the decoy addition would increase the number of comparisons among alternatives. Once again, since MDFT assigns the subjective value alterations to the comparative process, a behavioural difference should reflect a different attentional process. Therefore, in the ternary condition we expected a greater number of revisits for the target option compared to the same option in the opposite condition. It is worth stressing that this hypothesis complements, rather than contradicts, the previous one (H4): increasing the salience of the target and strengthening the comparative processes are different mechanisms, yet they could both have a role in eliciting the ADE (indeed, we expected to find evidence of both).

H6: The AD decoy boosts systematic comparisons with the target option, thus increasing the revisits number of the latter.

Comparative process: since recent models postulated a similarity-driven decisional process, we expected greater attention and comparisons among similar alternatives. In the ternary choice context, we predicted that an attentional focus on the decoy would produce a larger number of direct shifts towards the target option rather than towards the competitor one: the decoy acts by promoting comparisons (2.2), but these comparisons are also preferentially focused on the target option. Thus we supposed that the clear dominance structure draws the attention to the apparently more advantageous alternative because of its being more easily comparable (Roe et al., 2001; Hotaling et al., 2010).

H7: The decoy option creates a direct link with the dominant alternative; hence we expected more target-decoy than competitor-decoy attention shifts.

Predictive power of attention. According to previous literature on attention and decision making process, we expected that both revisits and fixations would be predictive of the subjects' final preference (Russo & Leclerc, 1994; Shimojo et al., 2003; Glaholt & Reingold, 2009; Krajbich & Rangel, 2011).

H8: Both revisits and fixations predict subjects' choices.

Dynamic plot of fixations: Lastly, in line with recent models of decision making, we postulated different fixation types during the decisional process. Indeed, after a preliminary and rapid scanning of the information, we predicted the emergence of slower attentional shifts, possibly indicative of a more careful deliberation (Russo & Leclerc, 1994; Krajbich & Rangel, 2011; Noguchi & Stewart, 2014). Moreover, we supposed ADE has a temporal and causal priority over the gaze cascade effect (Shimojo et al., 2003; Simion & Shimojo, 2007) that is elicited only in the final stage of the decisional process. For these reasons we also expected that the decoy had the greatest influence in the early stages of the process, since it should be quickly recognised as an irrelevant option (Huber et al., 2014)

H9: The dynamic plot of fixations is driven by ADE elicitation that overcomes the gaze cascade effect through an increasingly slower attentional and analytic process, thus largely disregarding the decoy option in its final stages.

3 Results

3.1 Statistical methods

For all statistical analyses, IBM SPSS 26.0 was used, and the significance level was set to $\alpha = .05$. Descriptive statistics were measured for each variable (mean, SD). All variables were checked for normality by Shapiro-Wilk test and for homoscedasticity by Levene test. In the case of violation of the above assumptions, non-parametric tests were used. Both parametric and non-parametric post-hoc multiple comparisons followed a statistically significant main effect, and multiple testing was corrected using Bonferroni correction. Due to the repeated measure design and some non-independent observations, we used a Wilcoxon signed-rank tests with two observations per subject when necessary. Similarly, taking into account our multilevel hierarchical setting, we used mixed effects models including both random and fixed effects. Each of the predictor variables was tested separately and each model was controlled for random subjects, items and subjects*magnitude effects. In the graphs in this article, error bars represent 95% confidence intervals.

3.2 Behavioural results

3.2.1 The decoy effect

H1: Asymmetric dominance effect elicitation in the ternary conditions; that is, AD decoy addition produces an increase in the target preferences.

Our first analysis aimed to verify the presence of ADE in an intertemporal domain. A Friedman test was conducted to analyse preference rates (LL preferences) in intertemporal choices: we divided items into 4 blocks of 15 items each, two for ternary choices (TI: ternary choices in which the decoy targets the immediate option; TD: ternary choices in which the decoy targets the delayed option) and two for binary choices (BI: binary choices used to create the TI ternary options; BD: binary choices used to create the TD ternary options). The Friedman test showed a significant difference across blocks, $\chi^2(3) = 16.51$, p = .001. The post-hoc analysis confirmed no preliminary differences between the two binary blocks. More importantly, it revealed a significant difference between BI (M = 6.60, SD = 3.92) and TI (M = 6.15, SD = 4.01, p =.043), between BD (M = 6.27, SD = 4.00) and TD (M = 7.13, SD = 3.48, p = .002), and between the two ternary blocks (p < .001; see Appendix for the details of the stimuli). All these differences were consistent with presence of ADE: decoys targeting LL increased preferences for that option, whereas decoys targeting SS increased choices for the immediate reward (left panel of Figure 2). The symmetric nature of this effect, both for SS- and LL-targeting decoys, suggest that our way of presenting the stimuli successfully boosted comparisons among options, thus allowing decoy effects on SS to overcome other competing biases, e.g., the immediacy heuristic. While this interpretation will require additional corroboration in future studies, this result further underscores the complex and subtle way in which contextual features affect the incidence and magnitude of decision biases.

3.2.2 Response times across conditions

H2: ADE elicitation, being based on a succession of systematic comparisons, results in longer response times: thus RTs should be affected by presence and strength of the effect.

To measure the impact of ADE elicitation on RTs, we compared RTs in ternary trials in which the decoy shifted the subject's preference towards its target (as compared to the corresponding binary trial) with RTs in ternary trials in which a preference for the competitor was unaffected by the decoy: trials where the subject preferred the target already in the corresponding binary choice were excluded from this analysis as irrelevant (it is not possible to know whether in this case the decoy is acting anyway, e.g., strengthening the pre-existing preference, or not), whereas trials were the shift occurred towards the competitor (very rare, just 8.14% of all ternary choices) were also irrelevant, albeit for different reasons – in these cases, it is unclear whether the decoy is failing to have any impact or is actually influencing decision making in the opposite direction. For each subject we calculated the mean RTs for preference shifts towards the target option and the mean RTs for trials where the decoy was ineffective, then we performed a Wilcoxon signed rank-test on the means: the analysis showed that choice reversals in the direction favoured by the decoy (from competitor to target) took significantly longer (M = 9803, SD = 4250) than trials where the decoy was unable to change preferences towards its target (M = 8221, SD = 2519; Z = 3.376, p = .001). Splitting the analysis for decoys targeting SS and decoys targeting LL confirmed the same pattern (TI: M = 9818, SD = 5175; BI: M = 7872, SD = 2397; Z = 2.110, p = .035; TD: M = 9908, SD = 5076; BD: M = 8449, SD = 3639; Z = 2.385, p = .017).

To further corroborate the hypothesis that ADE elicitation implies longer RTs, we compared subjects' RTs differed depending on the condition (binary – ternary) and the decoy direction (TI – TD): a non-parametric Friedman test was conducted to analyse RTs in the four blocks. It must be kept in mind that the binary condition is split into two sub-blocks simply based on what binary items were used to build, respectively, ternary choices with SS-targeting decoys and ternary choices with LL-targeting decoys: yet the two binary blocks thus defined, binary immediate and binary delayed, were perfectly balanced between them on all relevant metrics (delay lengths and magnitude ranges). The Friedman test showed a significant main effect of blocks ($\chi^2(3) = 195.83$, p < .001). The Wilcoxon signed-rank test post-hoc analysis revealed no baseline differences between the two

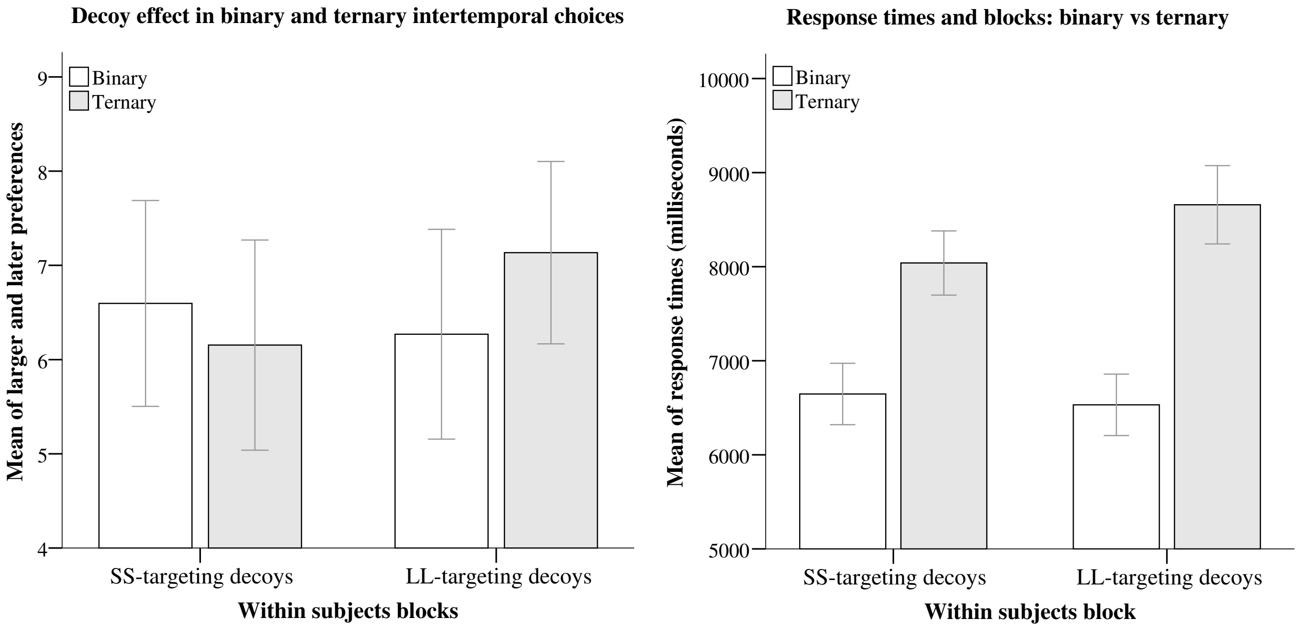

Figure 2: *Decoy effect* (left panel): preferences for delayed options. The ADE was elicited both comparing binary vs ternary (BI vs TI, p =.043; BD vs TD, p =.002) block and contrasting ternary blocks (TI vs TD, p <.001). *Response time* (right panel): mean of response time across blocks. Subjects took longer to answer when an AD decoy was present regardless of its direction (p <.001). Moreover, subjects spent more time in the TD block, in which the AD effect was greater (p =.012). Error bars are 95% C.I.'s.

binary blocks, as expected, whereas it pointed out a significant difference both between the BI (M = 6.65, SD = 4.64) and TI blocks (M = 8.03, SD = 4.87; p <.001), and between the BD (M = 6.53, SD = 4.65) and the TD blocks (M = 8.66, SD = 5.92; p < .001), as well as a significant difference between the TI and TD (p =.012). While the longer RTs in ternary blocks with respect to binary blocks is uninteresting (adding an option increases choice complexity and thus requires more time to be processed), the significance of the difference in RTs between ternary blocks further confirms the role of RTs as an indicator of the ADE effect: in fact, RTs were longer in the ternary condition in which the ADE effect was also stronger, i.e., TD (right panel of Figure 2), consistently with our hypothesis.

3.2.3 Response time in binary choices

H2B: LL preferences need a longer deliberative process, resulting in longer RTs.

RTs analysis on binary choices was mostly aimed at shedding new light on the debate about heuristic processes underlying intertemporal decision making. We assumed that choices for the LL option would take more time, since they would require inhibiting an immediacy heuristic that favours immediate outcomes.

A Wilcoxon signed rank test was conducted to compare RTs across preferences in binary choices. Due to repeated measurement, we used the mean of RTs with two observations per subject (the mean of RTs when SS was chosen vs the mean of RTs when LL was chosen for each subject). Results show a significant difference in the scores for SS selections (M = 6.95, SD = 3.39) and LL preferences (M = 7.27 SD = 2.61; Z = 2.233, p = .026): as predicted, opting for LL took longer than choosing SS, consistently with the hypothesis that future-oriented decisions involve inhibiting a prepotent response towards immediacy, and that such inhibition requires time to occur.

3.2.4 Magnitude effect in binary and ternary choices and RTs interaction

H3: The choice magnitude affects both delay discounting and response times.

Lastly, consistently with the previous literature, we predicted larger magnitudes to increase preference for LL both in binary and ternary choices. In order to test H3, a simple linear regression was calculated to predict LL selections based on the magnitude range (1: tiny; 2: small; 3: medium; 4: large; 5: huge) of choice items. A significant regression equation was found in both conditions (Binary: F (1, 258) = 130.71, p < .001, with an R2 of .336; Ternary: F (1, 258) = 106.28, p < .001, with an R2 of .292). Subjects' predicted LL responses are equal to −.277 + .950 (magnitude) dimension in the binary context and .131 + .842 in the ternary one. Sub-

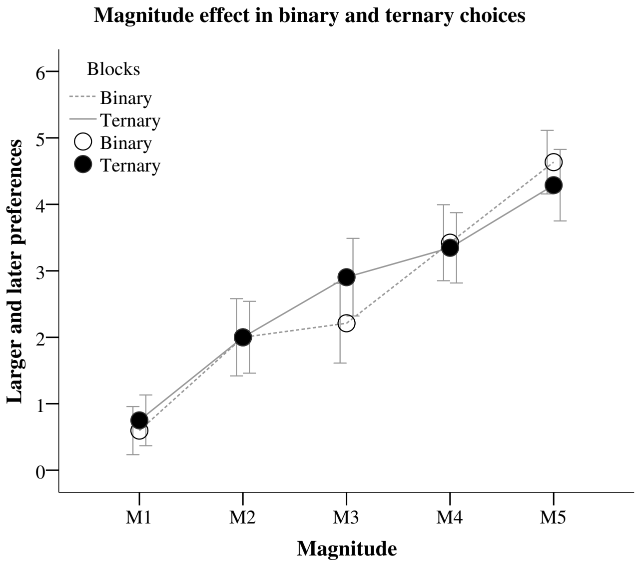

FIGURE 3: Magnitude effect in binary and ternary collapsed choices. In both domains, an increase in the amount corresponded to a relative decrease in the discounting rate (and so a greater number of delayed preference).

jects' average LL selections increased .950 (binary) and .842 (ternary) for each magnitude unit (Figure 3). This confirms our hypothesis on the role of reward magnitude in increasing LL preferences.

Moreover, two mixed effects models with random subject intercept were run to determine the relationship between magnitude (independent variable) and items' response times (in milliseconds; dependent variable). Results confirmed our hypothesis, revealing a positive significant association in both contexts (Binary: β = 350.10, t = 4.566, p < .001; Ternary: β = 406.35, t = 4.451, p < .001). Since we postulated a significant interaction between magnitude and RTs, the idea was that greater amounts would draw more attention, thereby triggering a more careful and time-consuming decisional process (for a different result in a binary context with hypothetical rewards, see Paglieri et al., 2013).

3.3 Eye-tracking results

Our eye-tracking analysis had a dual purpose: to investigate the decisional processes that lead to the choice and to understand how the decoy option is capable of altering the behavioural output. Basically, we wanted to clarify the attentional and cognitive processes elicited by the presence of a decoy. Therefore, our protocol was designed to test both an 'attentional hypothesis', for which the decoy would push the decision maker's attention on the target option making it more salient within the choice space (Shimojo et al., 2003), and a 'comparative hypothesis', for which the decoy would increase the target subjective value by triggering a series of comparisons between the options (Roe et al., 2001). Crucially, we do not consider these processes to be mutually exclusive: in fact, we expect to find evidence of both in our study, since they collaborate in making decoys effective. Nonetheless, it is a crucial feature of our design to be able to pinpoint what data support the attentional pathway to decoy effects, and what others confirm the role of comparative processes in the elicitation of those effects.

3.3.1 Fixation times on options and attributes: the attentional hypothesis

H4: The AD decoy presence makes its target more salient; thus an option should have longer fixation times when it plays the target role.

H5: The AD decoy makes the dominance attribute more relevant; thus that attribute will be fixated more in ternary contexts, in relation to the other one.

First of all, we focused on the target/competitor fixation times in the ternary context. The 'attentional' hypothesis posits that an essential role of the decoy during the decisional process is to shift the decision maker's attention to the target. Thus we examined the time spent on each option in ternary blocks, depending on whether it was the target or the competitor of the decoy: a repeated measures Friedman test was conducted to analyse fixation times for both SS and LL option (the amount of time spent looking at SS and LL) in the two ternary contexts (1: TI; 2: TD). Results clearly revealed a significant shift in the attentional focus depending on the decoy direction.

The Friedman test showed a significant main effect of the fixation times ($\chi^2(3)$ = 106.38, p < .001) and the post-hoc analysis confirmed an increase in fixation times for the target option. Indeed, SS fixation times in TI (M = 2.30, SD = 1.60) were significantly greater than SS fixation times in TD (M = 1.99, SD = 1.65; p < .001). Conversely, the LL option was fixed for significantly longer in TD (M = 2.76, SD = 2.26) compared to TI (M = 2.51, SD = 2.06; p = <.001). In other words, both SS and LL options were fixed for more time when they were the target of the choice, compared to when they were the competitor alternative (left panel of Figure 4).

This main result supports the attentional explanation of the decoy role. Subjects spent more time considering the target option, which likely affected their subjective values and prompted them to choose the dominant alternative.

Moreover, since fixation times were not directly comparable between different multialternative contexts, we ignored the time spent looking at the AD decoy in the ternary blocks, and we analysed fixation time only for SS and LL as a percentage (not including the time spent on the decoy option). As regards SS options we run a repeated measures Friedman test to analyse the relative fixation time in the four blocks (1: SS in BI; 2: SS BD; 3: SS in TI; 4: SS in TD). Our results

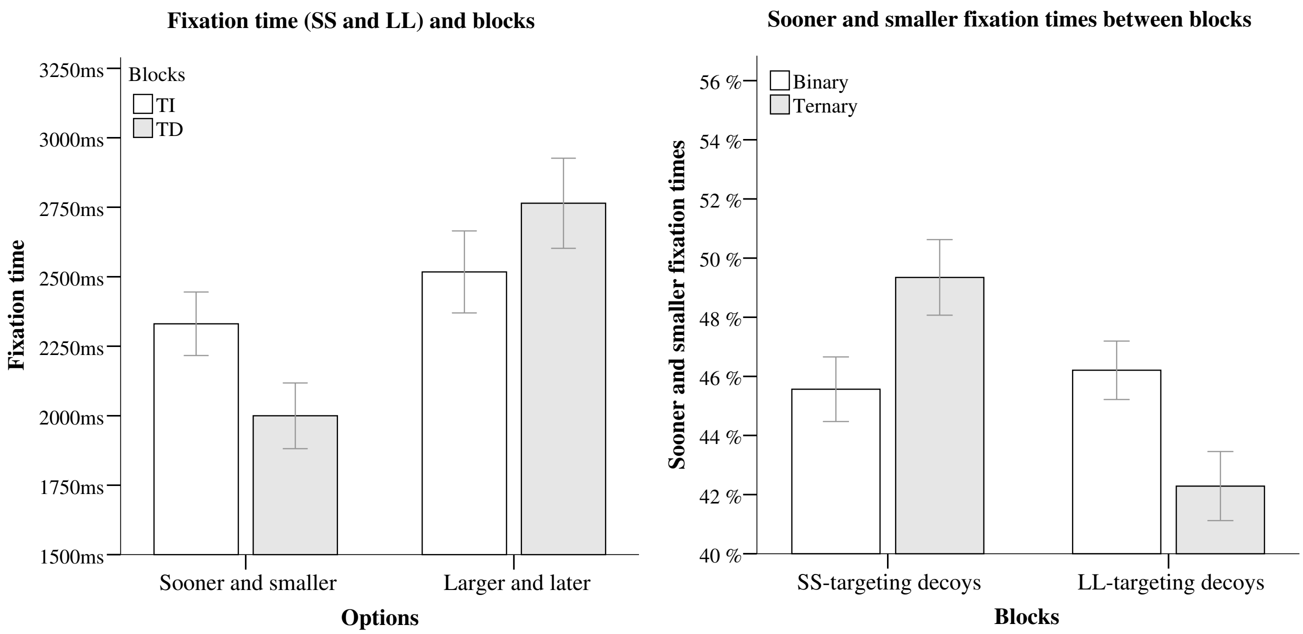

FIGURE 4: Fixation times (left panel): average fixation times in ternary contexts. Both in the TI and TD blocks target options were fixed for longer than competitors (p <.001). The right panel shows the increase and decrease of sooner and smaller options fixation times in the ternary blocks compared, as a percentage, to the relative blocks (p <.001).

showed a significant main effect of the block ($\chi^2(3) = 59.91$, p < .001). As expected, Wilcoxon signed rank test post-hoc revealed no differences between binary blocks (whose difference was purely nominal). However, we found a significant increase in the SS relative fixation time in the target condition (TI: M = 50.00, SD= 17.01) compared to both binary blocks (BI: M = 45.83, SD= 14.86, p < .001; BD: M = 46.82, SD= 13.38, p < .001) as well as a decrease in SS relative fixation time in the competitor block (TD: M = 42.59, SD= 15.84) compared with all the other blocks (p < .001). Since we were analysing the relative fixation time in each choice as a percentage, the Friedman test performed for LL options replicated the same pattern and identical significance levels (right panel of Figure 4). These results confirm that the decoy increases attention towards its target, both with respect to binary contexts (where no decoy is present) and in relation to ternary contexts in which the same option acts as a competitor, rather than target.

We also looked at the percentage of time spent fixating the dominance attribute (amount) in any of the options, in relation to the total fixation time on attributes. For each subject we calculated the mean percentage of time spent fixating on amount in each condition (BI, BD, TI, TD): a one-way repeated-measure ANOVA showed a significant main effect of blocks (F(3,147) = 12.992, p <.001, $\eta 2 = .210$) and post-hoc comparisons revealed the absence of any significant difference between the two binary blocks (BI: mean % = 53.17, SD = 4.98; BD: mean % = 54.26, SD = 5.12; NS), whereas the dominance attribute was fixated significantly more in in TI as opposed to BI (TI: mean % = 57.40, SD = 4.64; p <.001) and in TD as opposed to BD (TD: mean % = 55.96, SD = 5.20; p = .033). The higher percentage of fixation times in ternary contexts than in binary blocks confirm the role of decoys in shifting attention preferentially towards the dominance attribute, i.e., the attribute that determines the superiority of the target in relation to the decoy. This is likely to depend on the higher diagnosticity that the decoy confers to the dominance attribute: in our materials, in ternary choices amount was relevant to discriminate all three options, whereas delay was relevant only to compare the competitor to the other two.

It is interesting to speculate on the impact of the increased salience granted to the dominance attribute in modulating the effectiveness of decoys, depending on their target: in multi-attribute choices, directing attention towards one attribute may in fact result in a competitive advantage to the option that is superior with regard to that particular attribute. Such option, in turn, may either correspond to the target or to the competitor of the decoy. In the present study, decoys were always designed to have the same delay of their target: hence they shifted attention towards amount, that is, towards the attribute favouring LL choices. Thus this attentional shift may either support the direction of the decoy effect (e.g., in TD, where LL is the target of the decoy), or it could work against it (e.g., in TI, where LL is the competitor of the decoy). This may have a role in explaining why the decoy effect in this study, albeit present both in TI and TD, was larger in the latter than in the former: since in TI the decoy activates competing attentional process (more emphasis on SS, but also more emphasis on amount, in which SS is inferior to LL), this limits its power in shifting preferences towards its target. This interpretation, however suggestive, is not conclusive, since previous research offers alternative explanations to the lower effectiveness of decoys targeting SS, as discussed (e.g., the interference of an immediacy heuristic). Nonetheless, the attentional effect on attributes highlighted by these results suggest that how AD decoys are built (i.e., which attribute is used to express dominance) may have repercussion on the effectiveness of those decoys, depending on whether their target is the superior or inferior choice option on that particular attribute.

3.3.2 Target-competitor revisits: the comparative hypothesis

H6: The AD decoy boosts systematic comparisons with the target option, thus increasing the revisits number of the latter.

According to the comparative hypothesis, decoys exert their influence by increasing the comparisons with the target, due to the addition of a similar dominated option. As mentioned previously, the two alternative explanations of the decoy influence, not being mutually exclusive, can work simultaneously in shifting subjects' preference. In order to test the comparative hypothesis (H6), a repeated measures Friedman test was conducted to analyse revisits number for both SS and LL option (the number of times subjects returned to fix the target option during the choice) in the two ternary blocks (1: TI; 2: TD). The Friedman test revealed a significant main effect of the revisits number ($\chi^2(3) = 289.74$, $p < .001$), highlighting an influence of the decoy on the target revisits: in particular, a subsequent Wilcoxon signed rank test analysis between the different blocks showed an increase in revisits in the target condition (Figure 5). More specifically, SS options were revisited more times in TI (M = 4.13, SD = 2.67) compared to TD (M = 3.00, SD = 2.27; $p < .001$); symmetrically, LL alternatives were revisited more often in TD (M = 4.55, SD = 3.31) than in TI (M = 3.09, SD = 2.61; $p < .001$). Based on the reasonable assumption that a greater number of revisits involves a higher number of comparisons, these eye-tracking results confirm the effectiveness of decoys in triggering comparison with the target (comparative pathway): together with the impact of decoys on target salience (attentional pathway, see sections 3.3.3 and 3.3.5), this provides the most likely explanation of the behavioural impact of decoys in shifting preferences towards their targets. Once again, these two mechanisms, albeit conceptually independent, are convergent, rather than in conflict with each other: AD decoys both focus the subjects' attention on the target option, and prompts decision makers to keep evaluating that particular option during the whole decisional process, via multiple attentional shifts.

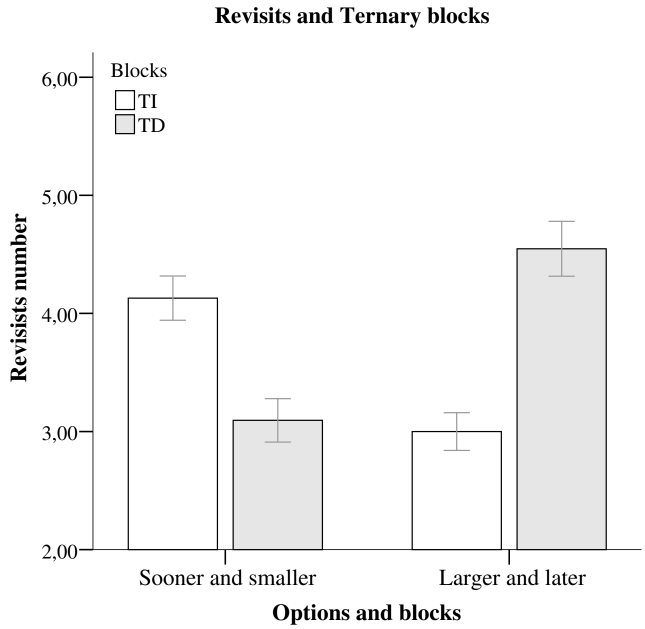

FIGURE 5: Mean of revisits for the target and competitor options in the ternary context. In both contexts (TI vs TD), decision makers, revisited the target option for a greater number of times ($p < .001$).

3.3.3 Target-competitor comparisons number: the comparative hypothesis

H7: The decoy option creates a direct link with the dominant alternative; hence we expected more target-decoy than competitor-decoy attention shifts.

Strictly speaking, results so far only show that the target is revisited more often than the competitor, whereas the assumption that this is due to an increase in comparisons between target and decoy remains to be demonstrated. To do so, we explored the comparative hypothesis from the decoy fixations point of view. Our idea was that processing the decoy would create an automatic link with the dominant option, thus producing an increase of comparisons between decoy and target, as opposed to attentional shifts between decoy and competitor. To test this hypothesis, two different paired samples Wilcoxon signed rank tests were conducted to compare attentional shifts in ternary choice context: since in our experiment we randomized the options' presentation order, we analysed only choice sets in which the decoy option was centrally located, since we needed the same distance between decoy and target and between decoy and competitor for the comparison to be meaningful. In this analysis we used the mean of target-decoy and competitor-decoy shifts with two observations per subject (the mean number of shifts of each type for that particular subject), due to our repeated measurement design.

In the TI block, results show that the target (SS) is compared to the decoy significantly more often than to the competitor (target comparisons: M = 2.90, SD = 1.21; competitor comparisons: M = 2.31 SD = .91; Z = 3.769, p < .001). Similarly, a dependent-samples Wilcoxon test in TD revealed a greater number of consecutive shifts between target (LL) and decoy (TD) (M = 3.10, SD = 1.19) than between competitor (SS) and decoy (M = 2.58, SD = .96; Z = 3.246, p = .001). This further confirms and specify the role of decoys in triggering comparisons specifically between the target and the decoy itself.

3.3.4 The role of attentional and comparative cues in predicting choice

H8: Both revisits and fixations predict subjects' choices.

So far results have shown that decoy can affect subjects' attention in two different and not mutually exclusive manners: by focusing the attention on the target option (attentional role) and by increasing the number of comparisons with the target, and in particular between target and decoy (comparative role). Although these processes remain distinct in nature, they are likely to converge in producing the behavioural result on choice: an increase in preferences for the target option.

On the attentional side, we proved that the addition of the decoy increases target fixation times: consistently with previous findings (e.g., evidence of the gaze cascade effect, Shimojo et al., 2003; Simion & Shimojo, 2007), the increased salience of the target option should have a causal role in producing the corresponding behavioural change. Indeed, a linear mixed effects model with the subject choice as the outcome of interest, both with target fixation time (the time spent on the target option during the evaluation procedure) and magnitude as fixed effects and item, subjects and subjects*magnitude as a random effect, proved a significant direct association between subjects choices and the target fixation time in both context (TI: $\beta = -.0005$, t = −5.184, p < .001; TD: $\beta = .0002$, t = 2.518, p = .012).

On the comparative side, we showed that the presence of the decoy increases the number of revisits for the target option. According to the MDFT, this finding should have a behavioural symmetric outcome. Our results fully confirmed this prediction: within-group and between-group comparisons were based on a mixed-effects linear regression model with random intercepts. Subjects choices (0=SS; 1=LL), was the dependent variable and target revisits number and amount magnitude the independent ones. Results revealed a significant interaction between preferences and target revisits both in TI ($\beta = -.033$, t = −5.786, p < .001) and TD condition ($\beta = .022$, t = 4.345, p < .001). In other words, the more subjects revisited the target option, the more likely they were to choose it. These outcomes fit well with the MDTF assumptions, since the revisiting (or comparative) process affected subjective values allocation, and thus the choice.

Finally, we verified that also specific comparisons between target and decoy, and not just number of target revisits, are predictive of the choice. We used a mixed effects linear regression model with subjects' choices as a dependent variable (0 = SS; 1 = LL), and the number of target-decoy shifts and items' magnitude being the two independent variables both in TI and TD. In TI, our model shows that a greater number of target-decoy comparisons is associated with an increased likelihood that the SS option has been chosen (β-TD-ShiftsNumber = −0.257, t = - 3.539, p < .001). Similarly, also in TD the model shows an association between subjects' choices and target-decoy comparisons (β-TD-ShiftsNumber = 0.250, t = −3.900, p < .001). Overall, these analyses confirm that, by increasing the number of direct comparisons between decoy and target, the decoy consistently boosts the likelihood for the subject to choose the target option: the more decision makers emphasize the dominance relationship between decoy and target, by comparing them more often, the more they choose the dominant option. These results are once again consistent with the hypothesis of a double role (attentional and comparative) for decoys in the elicitation of attraction effects.

3.3.5 The dynamic plot of fixations and its role in determining choice

H9: The dynamic plot of fixations is driven by ADE elicitation that overcomes the gaze cascade effect through an increasingly slower attentional and analytic process, thus largely disregarding the decoy option in its final stages.

In order to verify how long subjects keep comparing options during the decisional process, we looked at the dynamic evolution of fixations. This analysis can help disentangle the decoy effect from the gaze-cascade effect, by clarifying which of them is more likely to have temporal and causal priority. Here we expected to observe the gaze-cascade effect elicitation only in the subjects' last fixations, whereas the decoy would have expressed its causal role during the first stages of the choice process: basically, we hypothesized that first the decoy would determine what option becomes more salient, and then the gaze-cascade effect would further reinforce the impact of this greater salience on choice. In terms of empirical predictions, whereas MDFT predicts a stochastic allocation of the attention (Roe et al., 2001) until the subjective values of an option exceeds an individual threshold, the gaze cascade effect implies that the probability that a subject fixes the chosen option steadily increases over time (Shimojo et al. 2003).

In order to compare the effect of choice (either SS or LL), timing (when the fixation occurred) and block (TI vs. TD), we performed two mixed effects linear regression models. Our dependent measures were fixation times on SS (in the

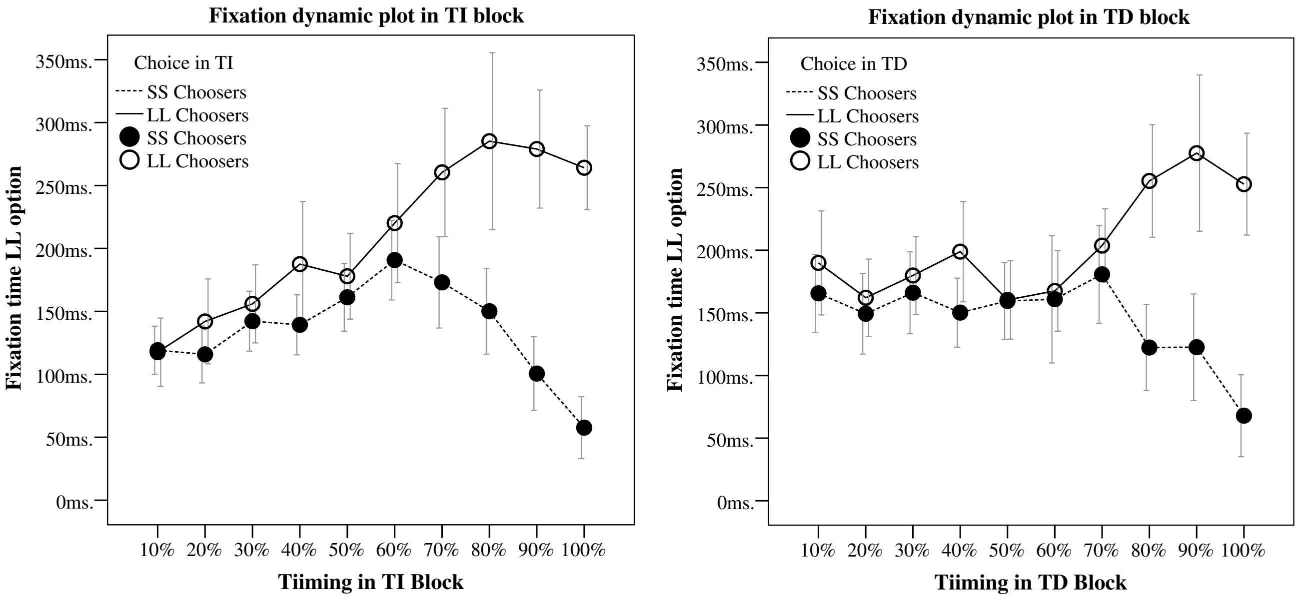

FIGURE 6: Dynamic plot of larger and later fixation times over the time course of the decision in TI (left panel) and TD condition (right panel): choice for SS and LL option are depicted by different line. The graphs show the attention polarization only in the last phases of the decision process ($p < .001$).

first model) and LL (in the second one). The fixed effects (independent variables) were subjects' choices (SS = 1; LL = 2), block (1 = TI; 2 = TD), magnitude range (from 1-tiny to 5-huge) and timing. The timing of each fixation (when the fixation occurred) was assessed by dividing each item into ten sub-periods in percentage. This meant that each time-cluster represented the attention allocation in relation to the relative time bins with each bin including 10% of the absolute fixation time per subject and item. Both our models revealed a significant association between option (SS and LL) fixation time and choice (Time on SS: $\beta = 55.17$, $t = 5.479$, $p < .001$; Time on LL: $\beta = -51.54$, $t = -4.715$, $p < .001$), timing (Time on SS: $\beta = 28.24$, $t = 11.554$, $p < .001$; Time on LL: $\beta = -21.72$, $t = -8.199$, $p < .001$) and choice*timing interaction (Time on SS: $\beta = -16.61$, $t = -10.499$, $p < .001$; Time on LL: $\beta = 17.49$, $t = 10.202$, $p < .001$), demonstrating a substantial difference in the attentional allocation depending on the passage of time and the final subject's choice. Moreover, as expected, we did not find a significant main effect of blocks, proving that this attentional pattern holds for whatever option the decoy is targeting.

These results are consistent with accumulation models since we did not observe any gaze-cascade effect before the final stages of decisions (Figure 6). Moreover, this outcome provides a more fine-grained understanding of the temporal dynamic of the comparative process elicited by the decoy: subjects continued to compare both relevant options until such comparison revealed a clear preference, but afterwards their attention became more and more focused exclusively on the soon-to-be chosen option (consistently with gaze cascade effects). Indeed, according to MDFT, decision makers are generally prone to compare values, but ADE is elicited only when this comparison produces a boosting effect on the target, and this requires a certain amount of time. In contrast, a great difference in fixations among SS or LL chooser since the beginning of the decisional process would have supported a predominant role of the gaze cascade effect, casting doubts on the presence of a genuine ADE. A series of Wilcoxon signed rank test comparisons among SS-choosers and LL-choosers revealed a significant difference ($p < .001$) only in the last phase of the decisional process (in the last 30% of the decision time), both for TI and TD, whereas in the first 70% of the decision time the difference was not significant (Figure 6).

Given the effectiveness of the AD decoy in shifting attention and preferences, here we wanted to investigate how the decoy processing changes throughout the decisional process, as well as some interpersonal differences in the comparative process. Due to repeated measurements, in order to verify the role of the decoy during different stages of the decisional process, a mixed-effects linear regression model with random intercepts was fit for the time spent on the decoy option as a percentage (as the independent variable) to estimate choice response times (dependent variable). In both contexts, we found a significant negative association between the percentage of time spent on the decoy and choice response time (TI β-Time-on-decoy = -50.660, $t = -2.931$, $p = .003$; TD β-Time-on-decoy = -38.279, $t = -3.096$, $p = .002$): the less time was devoted to consider the decoy (as a percentage of the total decision time), the longer subjects

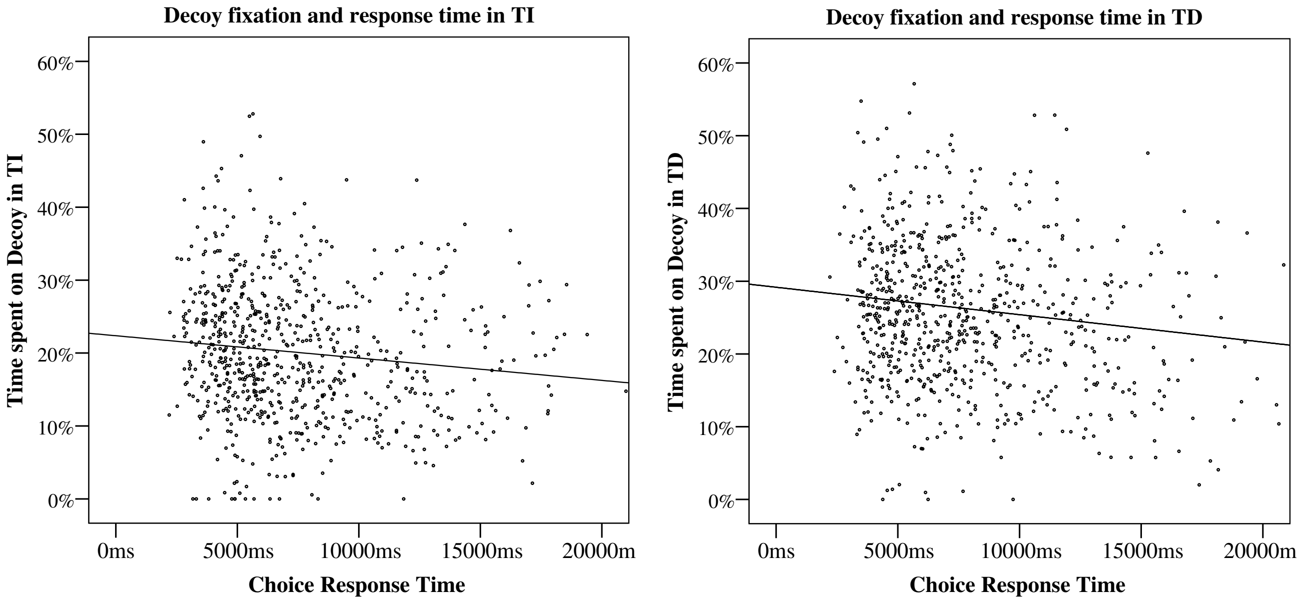

Figure 7: Decoy option fixation: Choice response time on individual and item fixed effects. The negative correlation in both contexts proved that subject tend to avoid to compare and revisit the decoy over time since subjects that took more time to show a preference, spent less time in the decoy fixation as a percentage.

took to make their choice. The most economical explanation of this finding is in line with the idea that the decoy, after successfully driving attention towards its target, is easily recognized as irrelevant and no longer considered; and since attention to the decoy in the later stages of choice is negligible, the longer it takes to a subject to make a choice, the less percentage of that time will be devoted to looking at the decoy (Figure 7).

To test this interpretation, according to which undecided subjects soon recognize the presence of an irrelevant option and thus ignore it in later stages, we used, both for TI and TD, a mixed effects linear regression model with random intercepts, subjects' fixation as a dependent variable (0 = SS and LL fixation; 1 = Decoy fixation), and the fixation sequence (1 = first fixation; N = last fixation) and items' magnitude range (due to repeated measurements) as the two independent variables. Both our models revealed a significant association between subjects fixation and fixation sequence, proving that a later fixation was associated with a decreased probability that the subject would fixate on the decoy option (TI β-AoI-Decoy-fixation = −.0038, t = −9.978, p < .001; TD β-AoI-Decoy-fixation = −.0042, t = −11.237, p < .001). Here the fixation sequence accurately represents the subject's decisional process, since it maps the whole path from the first fixation (right after the options appear on screen) to the last observation (right before the subject makes a selection). Our result indicates late fixations are very unlikely to focus on the decoy option, as predicted.

To further probe how decoys were processed by decision makers, we analysed the amount of revisits on the decoy amount (which was the feature highlighting the target dominance) in the ternary contexts by fitting a generalized linear

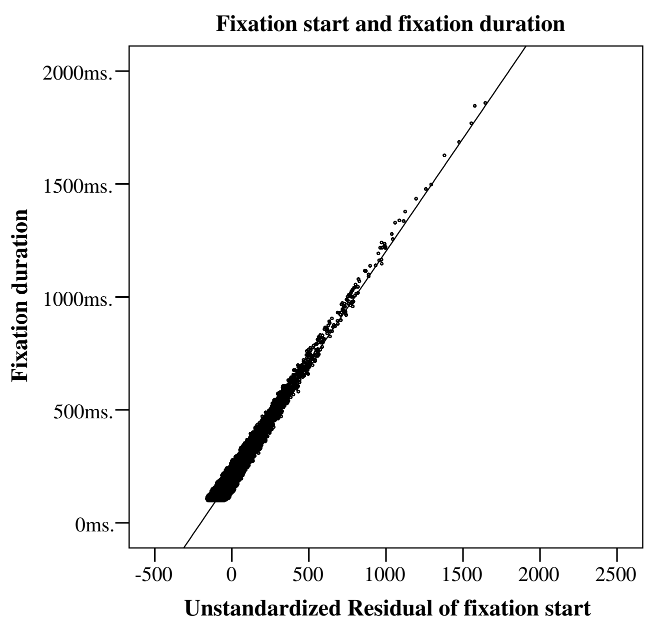

Figure 8: Decisional process. Residuals of a regression of fixation start on individual and item fixed effects. This correlation exhibits the attentional change during the decisional process. In the ternary contexts early fixations were usually shorter. On the contrary, at a later stage, choosers tend to compare slowly alternatives fixing the previously established subjective values.

mixed-effects model. The final choice of each item was the model dependent variable (0 = SS; 1 = LL), and the decoy amount revisits was the independent variable one, together with the magnitude range. We found a significant effect between subjects' choice and decoy amount revisits in both context (TI: $\beta = -.021$, $t = -2.667$, $p = .008$; TD: $\beta = .021$, $t = 2.791$, $p = .005$), suggesting that an increase in decoy amount revisits significantly increases the probability that subjects will choose the target option. This analysis was conducted because we supposed that the decoy observation directly enhanced target's subjective value. However, since the decoy was dominated on the amount value (the delay was the same as the target), the dominance's structure of the decoy could emerge only through a comparison between rewards sizes. This is the reason why the revisits of the decoy delay attribute were never associated with subjects' preferences, but only the decoy amount revisits revealed the comparative advantage of choosing the target option, pushing subjects to shift their preferences towards it. This pattern is also consistent with the Król & Król (2019) results, in which only the revisits for the attribute that highlighted the inferiority of the decoy pushed subjects to prefer the target option.

After finding evidence of both an attentional and comparative effect of decoys on choice, we wanted to test whether and how this dual influence may be modulated throughout different stages of decision making. To investigate this issue, a mixed-effects linear regression model was fit for the fixation start (as the independent variable; as well as items' magnitude range) to estimate the fixation duration (dependent variable) in the ternary collapsed blocks (regardless of whether the attention was on the immediate – SS – or delayed – LL – option). Our results highlighted a significant relationship between fixation start and fixation duration ($\beta = .002$, $t = 13.633$, $p < .001$), in line with previous models of decision making (Russo & Leclerc, 1994; Shimojo et al., 2003; Krajbich & Rangel, 2011; Noguchi & Stewart, 2014). It suggests that the first stage of information collection consisted of rapid attentional shifts. This process would rapidly detect and emphasize the dominance structure, thus enhancing the target's subjective value. At a later stage, subjects, having already assessed the basic information on each available option (including the manifest inferiority of the decoy in relation to the target), would carefully compare options through slower attentional shifts. These findings, besides corroborating the gaze cascade effect, suggest that slower, deliberate processes come into play at a later time during choice (Figure 8). This result is also consistent with dual-system theories of the evidence accumulation process; indeed the transition from rapid comparisons among alternatives to a more focused analytic process would reflect a cognitive switch between an intuitive and a deliberative system (Diederich & Trueblood, 2018).

4 General discussion

This study provides several insights on how decoys affect decision making in an intertemporal domain: in particular, we gathered corroborating evidence on both attentional and comparative processes responsible of eliciting decoy effects. The use of an eye-tracking paradigm proved essential in collecting the necessary data to support these converging yet distinct mechanisms, confirming the relevance of such methodology for the study of context effects on choice (see also Król & Król, 2019). Our analysis also highlighted the importance of response times in disentangling how different cognitive processes unfold over time, with respect to decoy effects: together with the role of RTs in assessing goodness of fit for competing models of contextual effects (Molloy et al., 2019) and the importance of developing computational models for dual systems theories that can account for both choice and timing data (Diederich & Trueblood, 2018), these results suggest that RTs should generally be used to complement choice data in studying the attraction effect and other contextual biases on choice. Another temporal dimension worth exploring concerns how attentional strategies evolve throughout different stages of decision making: our analysis confirmed that decoys exert their role at the very beginning of the choice process, whereas later on they are no longer processed, since attention has been successfully shifted towards their target; moreover, we were able to show how gaze cascade effects become apparent only in later stages of decision making, so that they act by strengthening the preference for the target elicited by the decoy, rather than by replacing the attraction effect.

In terms of behavioural results, we confirmed the effectiveness of AD decoys in affecting preferences in intertemporal choices, also when the decoy targets the immediate option: this last result is less common than the effectiveness of LL-targeting decoys (Kowal & Faulkner, 2016; Gluth et al., 2017; Marini & Paglieri, 2019), and it suggests that the particular presentational style used to visualize choice options was effective in facilitating the comparative processes instrumental to the elicitation of decoy effects. More broadly, it invites greater attention to the specific presentational devices used to describe choice options, since they may affect the impact of decoys on choice (on this point, with different motivations, see also Król & Król, 2019). As for RTs, we observed longer RTs whenever the decoy happened to have an impact on choice: this confirms a positive correlation between careful deliberation and the elicitation of decoy effects. Comparing RTs in choices resulting in different preferences also highlighted the slower decisional process required to opt for LL: this result is also consistent with some dual-system theories of decision making (i.e., the competing neurobehavioural decision system model (CNDS), Bickel et al., 2007; Loewenstein et al., 2015; Diederich & Trueblood, 2018, in risky decisions), which suggest a different neuronal activation between choices for immediate options (which are computed by limbic areas of our brain) and preferences for delayed rewards (elicited by a prefrontal located executive system).

Eye-tracking data, instead, were instrumental to pinpoint various distinct, yet not mutually exclusive ways in which decoys affect choice: an attentional pathway, causing an increase in salience of both the target option and the dominance attribute; and a comparative pathway, producing a higher number of consecutive attention shifts between decoy and target. In terms of potential for future investigation, the double-sided nature of the attentional impact of decoys is particularly thought-provoking: our results show that decoys focus attention both on the their target and on the dominance attribute. However, the latter effect may either favour or oppose preference for the target, depending on whether the target is superior or inferior to the competitor on that particular dimension: this effect, in turn, may impair or destroy the effectiveness of decoys, whenever the dominance attribute they emphasize projects unfavourably on their target. For example, in the intertemporal domain, amount-based AD decoys may be more effective when targeting LL than SS, since LL is better than SS in terms of amount; conversely, delay-based AD decoys may be more effective in targeting SS than LL, given that SS is better than LL as far as delay is concerned; mutatis mutandis, the same logic could be applied to any multi-attribute choice contexts.

Our results on the greater effectiveness of LL-targeting decoys are consistent with this speculation, since all our decoys were indeed amount-based, hence they emphasized the attribute that favours LL over SS. However, our study was not designed to test this particular prediction, and reviewing previous results on decoy effectiveness in intertemporal choices does not provide a clear answer either: some studies used only amount to create decoys (Marini & Paglieri, 2019), others used amount for SS-targeting decoys and delay for LL-targeting decoys (Kowal & Faulkner, 2016) or introduced decoys that were simultaneously dominated by their target on all dimensions (Gluth et al., 2017). Unfortunately, none of these methods allow to directly test whether decoys dominated on target-favouring attributes are more effective than decoys emphasizing target-opposing attributes. Thus we believe our results warrant further exploration in this direction in future studies, possibly using choice contexts where no confounding factor (e.g., the immediacy heuristic in intertemporal choice) may overshadow this potential effect.

To sum up, our study provides new details on how decision makers accumulate and integrate pieces of evidence during the decisional process, and how this affects choice outcome. We confirmed that decoys prompt subjects to fixate more frequently the target option and the dominance attribute, and that these attentional shifts increase preference for the target (especially when both effects converge, i.e., in TD); moreover, we found evidence of more frequent comparisons between alternatives of equal values on one of the attributes (decoy and target), and observed that these comparisons positively associate with preference for the target option. Finally, careful examination of attentional patterns throughout the whole choice process revealed how attention management strategies evolve during decision making in the presence of decoys: in particular, we were able to prove that gaze cascade effects are not a viable alternative explanation to the attraction effect (albeit they might further strengthen it), since they emerge only in the last stages of choice. Taken together, these findings strongly support theories of preference construction (e.g., Payne, Bettman & Johnson, 1992; Lichtenstein & Slovic, 2006), according to which decision makers are not expressing some pre-existing preference, but rather constructing option values during the choice process. If that is the case, as our results seem to suggest, then studying the fine-grained structure of this dynamic processes of preference construction is a key priority in the decision making literature, above and beyond the mere recording of choice anomalies: this, in turn, promotes further use of experimental methods naturally designed to gather evidence on the ongoing development of attention and value, such as eye-tracking and detailed reaction times analysis.

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Appendix

Table A1 shows the 15 binary and the 15 ternary TI items. Decisions consisted in a two or three options multiattribute intertemporal choice. During the task, the SS-LL-D location was counterbalanced as well as the up-down presentation of each value. Moreover, Table A1 reports the percentage of preferences for each displayed outcome.

Item	SS Option		LL option		Decoy Option		SS	LL	D
	Amount €	Delay	Amount €	Delay	Amount €	Delay	Choice %	Choice %	Choice %
Binary Immediate (BI)									
1	8	Today	10	2 weeks			90,38	9,62	
3	3	Today	10	18 weeks			80,77	19,23	
6	4	Today	11	18 weeks			90,38	9,62	
7	65	Today	80	2 weeks			55,77	44,23	
10	71	Today	88	2 weeks			67,31	32,69	
11	51	Today	88	6 weeks			71,15	28,85	
14	93	Today	160	6 weeks			61,54	38,46	
15	51	Today	160	18 weeks			73,08	26,92	
18	56	Today	176	18 weeks			61,54	38,46	
19	258	Today	320	2 weeks			25,00	75,00	
22	284	Today	352	2 weeks			36,54	63,46	
23	205	Today	352	6 weeks			53,85	46,15	
26	373	Today	640	6 weeks			19,23	80,77	
27	204	Today	640	18 weeks			28,85	71,15	
30	224	Today	704	18 weeks			25,00	75,00	
Ternary Immediate (TI)									
31	8	Today	10	2 weeks	7	Today	84,62	13,46	1,92
32	3	Today	10	18 weeks	2	Today	80,77	19,23	0,00
33	4	Today	11	18 weeks	3	Today	86,54	9,62	3,85
34	65	Today	80	2 weeks	58	Today	57,69	38,46	3,85
35	71	Today	88	2 weeks	64	Today	61,54	32,69	5,77
36	51	Today	88	6 weeks	46	Today	76,92	21,15	1,92
37	93	Today	160	6 weeks	84	Today	57,69	40,38	1,92
38	51	Today	160	18 weeks	46	Today	69,23	25,00	5,77
39	56	Today	176	18 weeks	50	Today	30,77	69,23	0,00
40	258	Today	320	2 weeks	233	Today	69,23	28,85	1,92
41	284	Today	352	2 weeks	256	Today	34,62	63,46	1,92
42	205	Today	352	6 weeks	185	Today	44,23	55,77	0,00
43	373	Today	640	6 weeks	336	Today	25,00	73,08	1,92
44	204	Today	640	18 weeks	183	Today	42,31	55,77	1,92
45	224	Today	704	18 weeks	202	Today	28,85	69,23	1,92

Table A2 shows the 15 binary and the 15 ternary TD items. Decisions consisted in a two or three options multiattribute intertemporal choice. During the task, the SS-LL-D location was counterbalanced as well as the up-down presentation of each value. Moreover, Table A2 reports the percentage of preferences for each displayed outcome.

Item	SS Option		LL option		Decoy Option		SS	LL	D
	Amount €	Delay	Amount €	Delay	Amount €	Delay	Choice %	Choice %	Choice %
Binary Delayed(BD)									
2	6	Today	10	6 weeks			90,38	9,62	
4	9	Today	11	2 weeks			94,23	5,77	
5	6	Today	11	6 weeks			94,23	5,77	
8	47	Today	80	6 weeks			67,31	32,69	
9	25	Today	80	18 weeks			71,15	28,85	
12	28	Today	88	18 weeks			67,31	32,69	
13	129	Today	160	2 weeks			53,85	46,15	
16	142	Today	176	2 weeks			61,54	38,46	
17	103	Today	176	6 weeks			67,31	32,69	
20	187	Today	320	6 weeks			38,46	61,54	
21	102	Today	320	18 weeks			53,85	46,15	
24	112	Today	352	18 weeks			50,00	50,00	
25	517	Today	640	2 weeks			23,08	76,92	
28	569	Today	704	2 weeks			17,31	82,69	
29	411	Today	704	6 weeks			23,08	76,92	
Ternary Delayed (TB)									
46	6	Today	10	6 weeks	9	6 weeks	84,62	13,46	1,92
47	9	Today	11	2 weeks	10	2 weeks	86,54	9,62	3,85
48	6	Today	11	6 weeks	10	6 weeks	88,46	9,62	1,92
49	47	Today	80	6 weeks	72	6 weeks	59,62	38,46	1,92
50	25	Today	80	18 weeks	72	18 weeks	65,38	34,62	0,00
51	28	Today	88	18 weeks	79	18 weeks	65,38	34,62	0,00
52	129	Today	160	2 weeks	144	2 weeks	36,54	59,62	3,85
53	142	Today	176	2 weeks	158	2 weeks	50,00	46,15	3,85
54	103	Today	176	6 weeks	158	6 weeks	46,15	50,00	3,85
55	187	Today	320	6 weeks	288	6 weeks	15,38	80,77	3,85
56	102	Today	320	18 weeks	288	18 weeks	55,77	44,23	0,00
57	112	Today	352	18 weeks	317	18 weeks	36,54	61,54	1,92
58	517	Today	640	2 weeks	576	2 weeks	19,23	76,92	3,85
59	569	Today	704	2 weeks	634	2 weeks	17,31	80,77	1,92
60	411	Today	704	6 weeks	634	6 weeks	25,00	73,08	1,92

Table A3 shows the 15 binary and the 15 ternary TI items. Decisions consisted in a two or three options multiattribute intertemporal choice. During the task, the SS-LL-D location was counterbalanced as well as the up-down presentation of each value. Moreover, Table A3 reports the percentage of fixations for each displayed outcome.

Item	SS Option		LL option		Decoy Option		SS	LL	D
	Amount €	Delay	Amount €	Delay	Amount €	Delay	Fixation %	Fixation %	Fixation %
Binary Immediate (BI)									
1	8	Today	10	2 weeks			55,41	44,59	
3	3	Today	10	18 weeks			49,52	50,48	
6	4	Today	11	18 weeks			44,84	55,16	
7	65	Today	80	2 weeks			51,15	48,85	
10	71	Today	88	2 weeks			40,14	59,86	
11	51	Today	88	6 weeks			50,18	49,82	
14	93	Today	160	6 weeks			41,89	58,11	
15	51	Today	160	18 weeks			47,56	52,44	
18	56	Today	176	18 weeks			37,97	62,03	
19	258	Today	320	2 weeks			44,51	55,49	
22	284	Today	352	2 weeks			41,18	58,82	
23	205	Today	352	6 weeks			44,75	55,25	
26	373	Today	640	6 weeks			37,25	62,75	
27	204	Today	640	18 weeks			44,82	55,18	
30	224	Today	704	18 weeks			35,61	64,39	
Ternary Immediate (TI)									
31	8	Today	10	2 weeks	7	Today	39,30	32,00	28,70
32	3	Today	10	18 weeks	2	Today	38,23	46,08	15,69
33	4	Today	11	18 weeks	3	Today	45,17	28,47	26,36
34	65	Today	80	2 weeks	58	Today	36,59	32,65	30,76
35	71	Today	88	2 weeks	64	Today	29,19	40,82	29,99
36	51	Today	88	6 weeks	46	Today	39,20	33,98	26,82
37	93	Today	160	6 weeks	84	Today	36,51	37,64	25,85
38	51	Today	160	18 weeks	46	Today	40,96	39,73	19,31
39	56	Today	176	18 weeks	50	Today	40,36	35,58	24,07
40	258	Today	320	2 weeks	233	Today	38,07	37,61	24,31
41	284	Today	352	2 weeks	256	Today	24,76	45,26	29,98
42	205	Today	352	6 weeks	185	Today	40,53	37,38	22,09
43	373	Today	640	6 weeks	336	Today	36,90	36,59	26,52
44	204	Today	640	18 weeks	183	Today	34,93	47,73	17,33
45	224	Today	704	18 weeks	202	Today	38,52	37,93	23,56

Table A4 shows the 15 binary and the 15 ternary TD items. Decisions consisted in a two or three options multiattribute intertemporal choice. During the task, the SS-LL-D location was counterbalanced as well as the up-down presentation of each value. Moreover, Table A4 reports the percentage of fixations for each displayed outcome.

Item	SS Option		LL option		Decoy Option		SS	LL	D
	Amount €	Delay	Amount €	Delay	Amount €	Delay	Fixation %	Fixation %	Fixation %
Binary Delayed(BD)									
2	6	Today	10	6 weeks			46,60	53,40	
4	9	Today	11	2 weeks			47,35	52,65	
5	6	Today	11	6 weeks			51,12	48,88	
8	47	Today	80	6 weeks			43,19	56,81	
9	25	Today	80	18 weeks			47,69	52,31	
12	28	Today	88	18 weeks			40,63	59,37	
13	129	Today	160	2 weeks			53,14	46,86	
16	142	Today	176	2 weeks			42,51	57,49	
17	103	Today	176	6 weeks			50,98	49,02	
20	187	Today	320	6 weeks			38,25	61,75	
21	102	Today	320	18 weeks			50,81	49,19	
24	112	Today	352	18 weeks			34,49	65,51	
25	517	Today	640	2 weeks			46,55	53,45	
28	569	Today	704	2 weeks			38,47	61,53	
29	411	Today	704	6 weeks			46,43	53,57	
Ternary Delayed (TD)									
46	6	Today	10	6 weeks	9	6 weeks	36,14	27,88	35,98
47	9	Today	11	2 weeks	10	2 weeks	27,33	35,35	37,32
48	6	Today	11	6 weeks	10	6 weeks	30,78	37,11	32,11
49	47	Today	80	6 weeks	72	6 weeks	32,69	47,06	20,25
50	25	Today	80	18 weeks	72	18 weeks	23,94	40,58	35,48
51	28	Today	88	18 weeks	79	18 weeks	22,30	42,11	35,60
52	129	Today	160	2 weeks	144	2 weeks	34,17	33,51	32,33
53	142	Today	176	2 weeks	158	2 weeks	28,66	37,12	34,22
54	103	Today	176	6 weeks	158	6 weeks	25,38	39,95	34,67
55	187	Today	320	6 weeks	288	6 weeks	32,44	45,53	22,04
56	102	Today	320	18 weeks	288	18 weeks	25,83	43,28	30,88
57	112	Today	352	18 weeks	317	18 weeks	21,20	46,74	32,06
58	517	Today	640	2 weeks	576	2 weeks	34,69	32,15	33,16
59	569	Today	704	2 weeks	634	2 weeks	27,86	43,91	28,23
60	411	Today	704	6 weeks	634	6 weeks	24,15	46,89	28,96