Inferiority, Not Similarity of the Decoy to Target, Is What Drives the Transfer of Attention Underlying the Attraction Effect: Evidence from an Eye-Tracking Study with Real Choices

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Inferiority, Not Similarity of the Decoy to Target, Is What Drives the Transfer of Attention
Underlying the Attraction Effect: Evidence from an Eye-Tracking Study with Real Choices

by

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Abstract

Recent studies reported that the attraction effect, whereby inferior decoys cause choice reversals, fails to replicate if the choice options are presented in a pictorial rather than abstract numerical form. We argue that the pictorial setting makes the similarity between decoy and target salient, while the abstract one emphasizes the inferiority relationship between them, crucial for the effect to occur. Thus, we used a novel experimental design in which both similarity and inferiority are equally easy to judge, their relative strength simple to manipulate, and choices incentivized rather than hypothetical. Using eye-tracking, we found that both the transfer of attention towards an undesirable target and choice reversal likelihood increase when the decoy is more strongly inferior but less similar to the target. This suggests that a key mechanism in the attraction effect is that, by virtue of its inferiority, a decoy projects a spotlight of attention towards the target, making it more attractive.

KEYWORDS: eye-tracking; choice reversal; attraction effect

One of the most prominent context effects in consumer choice is the attraction effect (Huber, Payne, & Puto, 1982). This occurs when choosing between different options, say A and B, each of which is better than the other in some respects. Adding a third option, C ('decoy'), that is in every respect worse than B ('target'), but still in some respects better than A ('competitor'), makes people more likely to choose B, even if they would have preferred A to B in the absence of C.

A number of existing theories, backed by behavioral experiments, have pointed to attention transfers as a key mechanism behind the attraction effect. For instance, Roe, Busemeyer, and Townsend (2001) proposed a 'Multialternative Decision Field Theory', whereby the switching of attention between choice option attributes determines the eventual choice. The theory highlights the fact that, on the one hand, when the decoy is very similar to the target but not clearly inferior, it can reduce the preference for the target via a 'similarity effect'. On the other hand, when the decoy's inferiority is apparent, it can increase the attractiveness of a highly similar target via lateral inhibition, drawing attention towards the attributes where it is superior (see also Ariely & Wallsten, 1995; Bhatia, 2013; Bordalo, Gennaioli, & Shleifer, 2013). The more recently developed 'Multiattribute Linear Ballistic Accumulator Model' (J. S. Trueblood, Brown, & Heathcote, 2014) also assumes an attentional mechanism, whereby the fact that the decoy is closer to the target than to the competitor results in more attention being allocated to the comparison between the difficult to discriminate decoy and target options, ultimately revealing and highlighting the superiority of the target. Finally, Ok, Ortoleva, and Riella (2015) theorized that, in a two-stage process, a decoy first acts as a 'spotlight', narrowing down a person's attention to an 'attraction region', before choosing from within this region at stage two (also see Lleras, Masatlioglu, Nakajima, & Ozbay, 2017 for a related 'limited consideration' model).

Despite terms like ‘attention’ or ‘saliency’ featuring prominently in these explanations, and despite eye-tracking being often used to investigate other forms of decision bias (e.g., Król & Król, in press), there has been little attempt to use it to study the visual attention patterns accompanying decoy-induced preference reversals. Such an analysis seems fruitful, because research on value-based choice (in the absence of decoys) demonstrated that attention guides choices in a positive feedback loop, whereby a stronger preference for an option causes more attention to be allocated to it, and vice versa (Ashby, Jekel, Dickert, & Glöckner, 2016; Krajbich, Armel, & Rangel, 2010; Reutskaja, Nagel, Camerer, & Rangel, 2011; Shimojo, Simion, Shimojo, & Scheier, 2003). Nevertheless, we are aware of only a very small number of process-tracing studies of context effects, most of which were based on functional magnetic resonance imaging (W. Hedgcock, Rao, & Chen, 2009; Hu & Yu, 2014; Li, Michael, Balaguer, Hecce Castañón, & Summerfield, 2018; Mohr, Heekeren, & Rieskamp, 2017), and only one of which used eye-tracking. In this study, Noguchi and Stewart (2014) found that, in scenarios that induce context effects, people compare alternatives in pairs, one attribute at a time. However, their otherwise comprehensive design did not allow for an identification of which individual choices were actually affected by decoys (that is, it is impossible to tell if a subject would choose differently from a given competitor-target pair in the absence of a decoy).

To address the above problem, similarly to Hedgcock, Rao, and Chen (2016), we used a repeated-measures design, in which subjects face each competitor-target combination both with and without a decoy (separated by other decision trials as well as distractor tasks). However, unlike any existing studies, we combined this type of a repeated-measures design with eye-tracking. To illustrate the purpose of this setup, consider the two-attribute choice problem depicted in Figure 1. Suppose that we have established that a given participant prefers option ‘c’

to ‘t’ in the absence of any other choice options. The question we ask in this study is: if we then present the participant with the same choice, but with a decoy that is slightly inferior but very similar to the target (‘d₁’) would it result in a greater transfer of visual attention from the competitor (‘c’) to the target (‘t’) than if we instead used a decoy that is highly inferior but not very similar to the target (‘d₂’)?

[Figure 1 about here]

The above question is all the more important given that it can be linked to the recent debate about the robustness of the attraction effect. In particular, the authors of two extensive replication projects have argued that the effect is only reproduced if the choice options are presented as combinations of abstract numerical attributes, but fails to occur under a more realistic, pictorial representation (Frederick, Lee, & Baskin, 2014; Yang & Lynn, 2014). We believe that the reason for the discrepancy is that the numerical representation makes the inferiority relationship between the decoy and the target salient, as it is easy for subjects to notice that one is worse than the other in terms of, for example, both the quality index and the price. In contrast, displaying options as pictures typically emphasizes the similarity between decoy and target – in most stimuli examples presented in the two replication studies it is immediately clear that two of the three options may be perceived as a group, e.g. one gets to choose between two very similarly packaged varieties of the same brand of popcorn and one visually distinct product of another brand. At the same time, as noted by Simonson (2014), this makes it very hard for subjects to tell which option in the pictorial replication studies is the dominated, inferior one, whereas, according to Huber, Payne, and Puto (2014) ‘attraction depends on the ability to identify the dominance relationship quickly and unambiguously’. Even in those pictorial replications in which inferiority is clear (e.g. displaying pictures of an orange, a fresh apple, and

a spoiled apple), the problem might, in turn, be that undesirable options are known to attenuate the attraction effect (Malkoc, Hedgcock, & Hoeffler, 2013).

A separate problem, raised by Lichters, Sarstedt, and Vogt (2015) in their extensive literature review, is that over 98% of studies of the attraction effect, whether pictorial or abstract, are based on hypothetical choices, typically using MTurk and similar online surveys. Thus, the results are potentially affected by subjects' lack of attention, motivation, and automatic response patterns (Lichters, Bengart, Sarstedt, & Vogt, 2017; Smith, Roster, Golden, & Albaum, 2016).

With this in mind, we sought to investigate the role of similarity vs. inferiority in the attraction effect via a design in which: a) both relationships are equally easy for the subject to observe, i.e. equally salient; b) the extent to which options are inferior or similar to one another is precisely measured and manipulated; and c) subjects receive whatever they select, i.e. choices are non-hypothetical. In particular, the first objective (a) is achieved by presenting the choice options in a spatial grid, i.e. as in Figure 1.

Based on the discussed abstract vs. pictorial discrepancy reported by recent studies, we hypothesized that introducing a decoy inferior to an option one did not choose in decoy's absence will transfer attention (measured by eye fixation duration) to the target from the competitor (that is, a greater proportion of the fixation time will be allocated to an unattractive target if a decoy dominated by that target is added to the choice set). However, this effect will be weaker if the decoy is more similar but less inferior to the target ('d₁' in Figure 1, as opposed to 'd₂'). If confirmed, such a result would indicate that the attentional spotlight cast on the target by virtue of its superiority rather than similarity to the decoy is strong enough to offset the natural tendency to perceive spatially close/similar objects as a group and divert more attention towards them (Kimchi, Yeshurun, Spehar, & Pirkner, 2016).

Finally, to demonstrate the potential real-world applications of our findings, we explored the possibility of predicting, based on attention to choice options in the presence of a decoy, whether the decoy actually influenced the subject's preferences, i.e. whether or not the choice would have been different if the decoy were absent. In particular, we expected that increased attention to both the decoy and the competitor despite choosing the target might indicate a 'genuine' preference for the competitor that has been altered by the decoy. We discussed how such an approach might be useful in the evaluation of real-world marketing strategies.

Method

Subjects

The experiment was carried out at a large private university, where a total of 68 undergraduate and postgraduate student subjects were recruited. Their average age was 21.88 (SD = 3.18), 39 of them were female, and all had normal or corrected to normal eyesight.

Stimuli and Design

Subjects repeatedly chose (without time limit) one out of two or one out of three bundles of two types of goods: (1) shopping vouchers redeemable at any store of a big supermarket chain, including a store located in the vicinity of the experiment location; (2) food and drink vouchers redeemable at the local university canteen. All monetary values stated below are in the local currency, a unit of which is worth approximately 0.3 USD. For instance, in a given choice trial a subject might be asked to choose one of the following two bundles: (1) a supermarket voucher worth 4 and a canteen voucher worth 16; or (2) a supermarket voucher worth 14 and a canteen voucher worth 8.

An example of how the choice was presented to subjects is illustrated in Figure 2. The setting was partly inspired by a typical retailer's taxonomical shelf design, where products that are more similar are located closer together, but where it is equally simple to locate products that are inferior in quality or price (e.g. basic, low-quality products are placed in the bottom shelves). This is known to facilitate the consumers' evaluation of the products and increases their satisfaction (Meier & Robinson, 2004; Mogilner, Rudnick, & Iyengar, 2008).

Accordingly, in our case, the subjects' assessment of both similarity and inferiority was facilitated by presenting the voucher bundles on a spatial grid, where each 'disk' corresponds to a single bundle. In the example in Figure 2, its X-axis position (or the number in the left half of the disk) represents the value of the supermarket voucher included in the bundle, and the Y-axis position is the value of the included canteen voucher. Thus, one bundle was inferior to another if positioned to the bottom left of it, while similarity was simple to judge based on proximity.

As explained in the 'Payoffs' section, our subjects were motivated to reveal their true preferences. As such, they were unlikely to be biased by the visual presentation of the choice options, with the grid only there to support their assessment of the relationships between them (as shown by existing research, visual decision support tools can help people during multi-attribute choice, see e.g. Samek, Hur, Kim, & Yi, 2016).

Nevertheless, to counterbalance potential artefacts associated with the relative positioning of the choice options, for half of the subjects the canteen and supermarket voucher values were instead indicated by the X and Y axis respectively (as expected, we found no difference between the two groups of subjects). Furthermore, as detailed later, the relative positioning of the choice options was included as an independent variable in the regression model (rather than held constant across trials) allowing us to control and investigate its effect on attention and choices.

[Figure 2 about here]

After every trial, subjects carried out a distractor task (Figure 3), i.e. needed to say if a random math inequality is true (e.g. ‘ $16 - 4 > 3 + 11$ ’), and were reminded which number in a disk representing each bundle corresponds to which type of voucher (this was done via an example bundle, randomly generated in each instance of the task to additionally obstruct any attempts at memorizing the previous choice options). The purpose of the distractor task was to avoid carryover memory/learning effects and psychological reactivity (Ahn, Kim, & Ha, 2015; Hutchinson, Kamakura, & Lynch, 2000), by removing the primary task (choice-related) information from short-term memory (Bjork & Whitten, 1974).

[Figure 3 about here]

Choice Trial Specification

In each of the first 30 trials of the experiment, each subject would choose one of two bundles. The composition of each pair of bundles was drawn randomly subject to a number of constraints. That is, we considered all pairs of bundles such that: a) one bundle in each pair included a higher-value canteen voucher than the other, which in turn included a higher value supermarket voucher; b) the value of each type of voucher included in each bundle was at least 4 (to allow for an inferior bundle to be added later – see below) but at most 18, and was a multitude of 2 (consistent with the resolution of the grid, and to allow for enough distance between the areas of interest). We drew the pairs of bundles randomly from this set, independently for each subject and without replacement (ensuring that no choice sets were duplicate within subjects). We treated the first three trials obtained in this way as training, familiarizing subjects with the problem.

For each of the following 27 trials (trials 4 to 30), we constructed an additional, ‘matching’ trial, by adding a third, decoy bundle to the original two. The decoy was set randomly on each occasion, but always inferior to one (and only one) of the other two bundles (target). That is, the decoy was drawn from the set of bundles which: a) contained strictly less of one type of voucher and no more of the other type of voucher than one of the existing two bundles (the target), but strictly more of one type of voucher (and strictly less of the other type) than the competitor; b) contained at least 2 but at most 16 of each type of voucher (a multitude of 2). In the example shown in Figure 2, the matching trial would include a decoy located either north of bundle 2 but to the south-west of bundle 1, or east of bundle 1 and to the south-west of bundle 2.

The 27 matching trials were scheduled after the initial trials, in a randomized order. The reason for this relative timing of the two blocks was that, in the first instance, we wished to elicit each subject’s genuine preference between the competitor and the target without any current or past exposure to decoys. At the same time, in the ‘Results’ section we report that the distractor tasks were apparently successful in eliminating the influence of subjects’ potential recollections of the initial trials on their behavior and attention patterns in the matching trials, i.e. the ordering of the blocks was unlikely to interfere with our study of choice reversals in the matching trials.

Payoffs

Subjects were told that, upon completion, they would receive a single voucher bundle, drawn randomly from the set of the bundles they selected throughout all trials. This kind of random lottery payoff mechanism is often used, as it is effective in preventing portfolio building strategies and ensuring the independence of actions across trials, while allowing for ‘real-world consequences’ of choices (Cubitt, Starmer, & Sugden, 1998). On average, subjects received an

equivalent of 7 USD in vouchers, and the whole study took 25 minutes to complete (including the reading of instructions, eye-tracking calibration, and the distractor tasks).

Results

Measurements and data pre-processing

For each subject and each of the trials numbered 4 to 57 (i.e. skipping the training trials), we identified the eye fixations that occurred between displaying the choice screen and the subject submitting the choice (a fixation is a pause of eye movement on any part of the visual field, representing the subject's gaze being fixed on a specific point on the screen; see the appendix for details of the fixation detection procedure). We computed the total duration (in milliseconds) of all fixations directed at each of the disks representing the available choices. Henceforth, by ‘attention to option X’ we mean the total duration of fixations directed at the disk representing X. For each pair of matched trials (the initial trial and its later matching trial including a decoy), we identified the bundle that was chosen (preferred) in the initial trial – let ‘P’ denote this bundle, and let ‘NP’ denote the other bundle, the one that was not chosen (preferred) in the initial trial. Accordingly, we calculated the value of a variable we term ‘attention reversal’ (between the two trials), defined as follows:

$$\log \left[\frac{\text{attention to NP in the matching trial} / \text{attention to P in the matching trial}}{\text{attention to NP in the initial trial} / \text{attention to P in the initial trial}} \right]$$

Thus, attention reversal is positive when more attention is allocated to NP relative to P in the matching trial compared with the initial trial, and negative if the opposite occurs (the log-ratio transformation is used to normalize the comparison outcome). In other words, the greater the shift of attention between the initial and matching trial – away from the option chosen in the

initial trial and towards the option not chosen in that trial – the greater the attention reversal.

Henceforth, we will at times for brevity refer to the option not chosen in the initial trial (NP) as the ‘less preferred’ option, and to P as the ‘more preferred’ option.

To determine the potential role of the decoy in attention reversal, for each pair of matched trials we also specified the following two variables:

(1) ‘target-preferred’, a binary variable, taking a value 1 if the target option in the matching trial was P, i.e. if the decoy was set inferior to the more preferred option; if this was not the case, the variable took a value 0

(2) ‘proximity-to-target’, a continuous variable, equal to the difference between the Euclidean distance between the decoy and the competitor and a similar distance between the decoy and the target (using a log-ratio of the two distances instead does not cause a qualitative change of the results; also note that the reason why the two distances are not considered as separate variables is because it is impossible to change one without changing the other, and due to their strong negative correlation including both in a regression model would cause multicollinearity).

Lastly, an alternative dependent variable that we used in a separate model was ‘choice reversal’ (between the matching and initial trial). This was a binary variable taking a value 1 if in the matching trial the subject chose the bundle she did not choose in the initial trial (otherwise, it took a value 0). Such choice reversals occurred in 19% of matched trial-pairs.

Checking for memory carryover effects

To begin with, we wanted to check if our distractor task was successful in removing any carryover memory effects, i.e. if the subjects’ behavior in the matching trials was not influenced by their previous exposure to the corresponding initial trials. To this end, we estimated a mixed-effects binary logistic regression model in which each pair of matched trials by a given subject

constituted a single observation, with random intercept and slope effects clustered by subject to allow for correlated errors. The dependent variable was ‘choice reversal’, and the sole independent variable was the number of trials separating the initial trial from its matching trial. We found no significant effect between the two variables ($\beta = -0.004$, $t = -0.522$, $p = .602$) suggesting that a reduced time difference between the two matched trials did not significantly increase the likelihood that a subject's choice would be the same in both of them. In fact, the same was true for the relationship between the time difference and attention reversal ($\beta = 0.002$, $t = 0.829$, $p = .407$).

The influence of inferiority vs. similarity on attention reversal

Following this initial check, we proceeded to the main focus of our investigation, namely the effect of ‘target-preferred’ and ‘proximity-to-target’ on attention reversal. As a prelude to the main analysis, Table 1 shows the average attention reversal depending on the values of the two independent variables in question. In general, attention reversal tends to be positive on average, possibly due to the presence of the decoy distorting the attentional bias towards the preferred option in the initial trial. However, it appears that the difference between the attention transfer when target-preferred = 1, compared with target-preferred = 0, increases with proximity-to-target. This would suggest that the attention transfer to the less preferred option brought about by targeting it, rather than the more preferred option, with an inferior decoy, is greater when the decoy is more strongly inferior but less similar to the target (in fact, for high proximity-to-target, we observe a ‘repulsion effect’ of the decoy instead of attraction).

To evaluate the statistical significance of the above effects of the way in which the decoy is set, we estimated a mixed-effects linear regression model, again with each pair of matched

trials constituting a single observation and random intercept and slope effects clustered by subject to allow for correlated errors. The dependent variable was now ‘attention reversal’, and the independent variables were the ‘target-preferred’ and ‘proximity-to-target’ variables described above (as well as their interaction). We dropped those pairs of matched trials in which either: a) the subject selected the decoy bundle in the matching trial (2% of trial pairs); b) fixations were not recorded in at least one of the two matched trials due to a technical malfunction, looking away from the screen, blinking etc. (a further 9% of trial pairs); or c) the subject only looked at one of the available options in either of the matched trials, making it impossible to calculate the value of attention reversal (10% of trial pairs; clipping the log-ratio values instead of dropping these trial pairs does not cause a qualitative change of the results). The fixed effects estimation results (based on robust covariances) are presented in Table 2.

[Table 2 about here]

The fact that the model intercept is significantly positive ($\beta=0.702$, $p<.001$) indicates that, when the decoy is inferior to the ‘less preferred’ option (not chosen in the initial trial) and equally distant from the target and the competitor (target-preferred = proximity-to-target = 0), then in the matching trial subjects allocate more attention to the less preferred option (relative to the more preferred one) compared with the initial trial. In other words, a decoy equally similar to both options, but inferior to the less preferred one, causes a transfer of attention towards it.

The significantly negative coefficient estimate of ‘target-preferred’ ($\beta=-0.724$, $p<0.001$) means that making the decoy inferior to the more preferred option (instead of the less preferred one), but keeping its distance from the (new) target similar to the distance from the competitor (low proximity-to-target), results in a greater proportion of attention being allocated to the more

preferred option. In fact, when proximity-to-target = 0 and target-preferred = 1, the estimated attention-reversal towards the less preferred option becomes (slightly) negative. This suggests that, given a low proximity-to-target, attention only transfers towards the less preferred option if the decoy is inferior to it rather than to the more preferred option.

Most importantly, the significantly negative estimate of ‘proximity-to-target’ ($\beta=-0.082$, $p=0.002$) indicates that, when the decoy is inferior to the less preferred option (target-preferred = 0), then the smaller the extent to which it is inferior (and hence the more similar / closer to the target it is relative to competitor), the smaller the transfer of attention towards the (less preferred) target option. Accordingly, the significantly positive estimate of the ‘target-preferred*proximity-to-target’ interaction term ($\beta=0.135$, $p=.006$) indicates that the attention transfer to the less preferred option brought about by targeting it, rather than the more preferred option, with an inferior decoy, is greater when the decoy is more strongly inferior but less similar to the target. This tendency can also be seen in Figure 4, illustrating the regression results, with the highest estimated transfer of attention towards the less preferred option (left panel, warm colours) obtained for decoys that are strongly inferior but not very similar/close to that option.

[Figure 4 about here]

The influence of inferiority vs. similarity on choice reversal

To verify if the decoy-induced reversals of attention between the options translated into choice reversals, we estimated a separate mixed model (this time, a binary logit one), with the same fixed and random effects but with ‘choice reversal’ as the dependent variable. The fixed effects estimation results (based on robust covariances) are presented in Table 4, preceded by the raw frequencies of choice reversal (depending on the two independent variables) shown in Table 3.

324 [Table 3 about here]

325 [Table 4 about here]

326 In analogy with attention reversal, it seems from Table 3 that the frequency of choice
327 reversal decreases with proximity-to-target when target-preferred = 0 but (in almost all cases)
328 increases with proximity-to-target when target-preferred = 1. Consequently, the difference
329 between the frequency of choice reversal when target-preferred = 1 vs. when target-preferred = 0
330 increases with proximity-to-target. This would suggest that the increase in the likelihood of
331 choosing the less preferred option brought about by targeting it, rather than the more preferred
332 option, with an inferior decoy, is greater when the decoy is more strongly inferior but less similar
333 to the target.

334 Similarly, the regression coefficient estimates shown in Table 4 are all significant and
335 (apart from the intercept) have the same signs as those in Table 2¹. Specifically, we find that,
336 when the decoy is set inferior to the less preferred option (target-preferred = 0), then the smaller
337 the extent to which it is inferior (and hence the larger ‘proximity-to-target’), the smaller the
338 chance of a choice reversal ($\beta = -0.396$, $p < .001$). Additionally, the significantly positive estimate
339 of the ‘target-preferred*proximity-to-target’ interaction ($\beta = 0.636$, $p < .001$) indicates that the
340 increase in choice reversal likelihood brought about by targeting it, rather than the more

¹ Note that the fact that the intercept is not significantly different from zero simply means that the probability of choice reversal when target-preferred = proximity-to-target = 0 is not significantly different from ½. As the link function is different in each case and ‘zero’ has a different interpretation, this (null) result does not mean that the current relationship is not consistent with the one estimated in Table 2.

preferred option, with an inferior decoy, is greater when the decoy is more strongly inferior but less similar to the target.

Given the apparent link between the properties of the decoy on one hand and both attention and choices on the other, it seems natural to consider a model in which both attention reversal and choice reversal are present at the same time. For example, one might wonder whether attention reversal mediates the relationship between the decoy and choice reversal demonstrated in Table 4. However, apart from the technical difficulties of carrying out a mediation analysis within a mixed-model with a continuous mediator and a binary outcome variable, the complex, bi-directional nature of the attention-choice link we mentioned in the introduction is what prevents us from doing so. In particular, it is likely that the properties of the decoy affect, in the first instance, both attention to the choice options and a latent preference towards them. At the same time, the emerging preference is bound to influence attention, and vice versa, until a choice is finally made according to the preference at the time.

In Table 5, we present an auxiliary regression, which differs from the one in Table 4 in one feature only – namely that attention-reversal is included as an independent variable. As expected, this suggests a positive link between attention-reversal and preference-reversal ($\beta_{\text{attention-reversal}} = 1.956, p < .001$), while the other coefficient estimates are similar to those in Table 4. Although this might suggest that attention does not mediate the link between the decoy and choices, one should interpret the results of the model in Table 5 with caution, due to the fact that attention-reversal and choice-reversal may be co-determined by the latent preference variable that is omitted from the model, and the resulting endogeneity problem could bias the regression estimates.

Despite the lack of a straightforward causal relationship between attention and choice, we believe that our results so far suggest that the link between them could potentially be exploited for predictive purposes. In particular, we now explore the possibility of predicting, based on attention to the choice options in the matching trial, whether or not a choice reversal has taken place.

Detecting choice reversals based on eye-data

Our aim here was to check if it is possible to use eye-data to detect choice reversals *ex-post*, i.e. to determine whether or not a subject who chose the target did so because of or regardless of the decoy. While not central to our hypothesis regarding the attentional mechanism underlying the attraction effect, this analysis could have important practical implications. If successful, it would indicate, for example, that online retailers might in the future use their customers' increasingly easy to obtain eye-data (e.g. from smartphone cameras) to determine if decoys that they deployed actually change the choices of individual consumers. For example, suppose that a retailer wants to establish which 'types' of consumers (say, those who spent a lot at its online store in the past vs. those who did not) are most susceptible to the attraction effect and can be influenced by decoys. Suppose further that a similar fraction of consumers in each group who were exposed to decoys have nevertheless opted for the competitor options, i.e. were clearly not influenced. However, those 'low-spenders' who chose the target tended to focus their attention on it while ignoring the decoy and the competitor. In contrast, the 'high-spenders' who chose the target tended to look at the competitor and the decoy a lot more. Should the retailer conclude that both groups were similarly influenced by the decoy, or perhaps the 'high-spenders' were more strongly influenced but also liked the target options less in the first place, giving rise to a similar overall proportion of target purchases? While such questions could eventually be

answered by continued experimentation with product offerings and analysing the aggregate sales, using eye-data could potentially help to more quickly determine which individual consumers' choices were successfully altered.

With such practical applications in mind, we wished to verify if the prediction of choice reversals from attention measures can be done 'out of sample', based on a model estimated on data obtained from other people (e.g. through market research). Hence, we conducted a cross-validation procedure using data from those matching trials in which the target was chosen.

To predict choice reversals, we used a mixed effects logistic regression model with random subject intercept, 'choice reversal' as a dependent variable, and the proportional attention to the competitor and target (computed as a fraction of total fixation time) being the two independent variables (the proportional attention to decoy was thus redundant and not included). In Table 6, we report the model estimated for the entire sample of 68 subjects. This indicates that increased attention to the competitor (not chosen by the subject) is associated with an increased likelihood that the competitor has been chosen in the initial trial, i.e. that a choice reversal has taken place ($\beta_{\text{attention-to-competitor}} = 8.085, p = .001$). However, this effect is weaker when attention to the chosen target bundle is larger, which means, for a given attention-to-competitor, that attention to the decoy is smaller ($\beta_{\text{attention-to-competitor} * \text{attention-to-target}} = -6.935, p = .048$). In other words, the choice is more likely to have been altered by the decoy when attention to both the decoy and the competitor is large, perhaps indicating a preference for the competitor that is 'suppressed' by the decoy.

Moving on to the actual cross-validation procedure, for each subject, we estimated the same model as the one in Table 6, but using data from the remaining 67 subjects. In each case,

we then used the model to estimate the choice reversal likelihood in the choice trials of the one subject whose data we set aside.

Having saved the cross-validated regression scores estimated for each subject, we then conducted a signal detection analysis to evaluate the overall out-of-sample predictive power. In particular, for each cross-validation fold, we computed a receiver operating characteristic curve (ROC) that combines all possible false positive – sensitivity pairs (points) that would obtain depending on where we set the threshold value of choice reversal likelihood estimated by the regression model above which a prediction of a choice reversal is made. For instance, a retailer may take a ‘liberal’ approach and judge as effective all those decoys it used where the estimated choice reversal likelihood is not extremely low. In contrast, a ‘conservative’ retailer might stop using all decoys that do not achieve a high choice reversal likelihood. The total area under the ROC (‘AUC’) is a measure of the overall signal detection power, and the overall potential of eye-data to inform such decisions across all possible threshold values. Formally, the AUC is equivalent to the probability that the likelihood of choice reversal estimated for a randomly chosen trial in which choice reversal occurs is higher than for a randomly chosen trial in which it does not occur, and it is also equal to the value of the corresponding Wilcoxon-Mann-Whitney test statistic.

In our case, we found the mean AUC to be equal to 0.62, with a 95% Confidence Interval [.579; .663], obtained using the method of computing confidence intervals for cross-validated AUC estimates for pooled repeated measures data sets developed by LeDell, Petersen, and van der Laan (2015). Thus, the mean AUC was significantly above the chance level of 0.5 (whereby a choice reversal is predicted by chance in a given fixed proportion of cases).

Discussion

Although several theories (Roe et al., 2001; J. S. Trueblood et al., 2014, and others outlined in the introduction) pointed to attention transfers as a key mechanism behind the attraction effect, little or no process tracing evidence to support this role of attention has been provided so far. Similarly, while recent work has examined other context effects in non-hypothetical choices (Pinger, Ruhmer-Krell, & Schumacher, 2016), research on the attraction effect has been predominantly based on hypothetical ones.

The present experiment combined eye-tracking and real economic consequences of choices in a spatial grid design that allowed subjects to identify and assess both similarity and inferiority relationships between choice options with similar ease. The relative strength of these two relationships could be quantified, manipulated, and was included in the regression models as an explanatory variable. The aim was to investigate whether the failure to replicate the attraction effect under pictorial rather than abstract choice visualization could be explained by the fact that the abstract choice presentation makes the inferiority relationship between the decoy and target salient, while the pictorial presentation emphasizes their similarity.

We found that attention is transferred from one's more preferred choice option to the less preferred one if a decoy option is set inferior to the less preferred option (rather than the more preferred one). Crucially, this transfer of attention was stronger when the decoy was less similar and hence more inferior relative to the target, suggesting that inferiority rather than similarity is key for the attentional spotlight effect to occur.

What makes this result particularly compelling is that the spatial grid presentation of choices made similarity easy to perceive by virtue of it being represented by visual proximity. Existing eye-tracking research suggests that objects that are close to each other are more likely to

be seen as a group and tend to attract more attention (Kimchi et al., 2016). Thus, one would expect a greater transfer of attention to the target if the decoy is more similar and closer to it. The fact that a significant opposite tendency occurs indicates that the ‘attentional spotlight’ due to the decoy’s inferiority to the target must be strong, as we see decoys that are further away but more inferior to the target result in more attention being allocated to the latter.

Importantly, the decoy-induced transfer of attention seems well aligned with choice reversals, as we found that these are more likely if a decoy is set inferior to one’s less preferred option but further away from it, so that it is less similar but more inferior relative to the target. In other words, the circumstances that increase the attentional transfer also make choice reversals more likely.

It has been argued that the attraction effect might not replicate due to the heterogeneity of subjects’ preferences artificially reducing its aggregate measures in between-subject designs (Simonson, 2014). For instance, some people might be repulsed rather than attracted by the decoy, while others might be unaffected due to strong preferences (Farmer, Warren, El-Deredy, & Howes, 2016) or a clinical condition (Farmer, Baron-cohen, & Skylark, 2017). In the words of Huber et al. (2014), ‘because of heterogeneity in our goals and search experiences, it may be difficult to identify whether uncovering dominance altered a decision; [...] more work in eye tracking and neuroscience is needed to detect the impact of idiosyncratic dominance on choice’. Our use of eye-tracking combined with mixed-models addresses these issues and demands in two ways. First, the fact that we obtain significant results while allowing for random intercept and slope effects suggests that the overall effect of the decoy’s similarity vs. inferiority to target is strong relative to the between-subject variation in this respect. In other words, the overall effect is significant even after accounting for subject heterogeneity. Additionally, thanks to the

repeated-measures design, we are able to identify the attentional patterns accompanying choice reversals at an individual subject level, and to determine the within-subject effect of similarity vs. inferiority on both attention and choice. We found that these effects are considerable, ranging from an attraction towards the target for low proximity to target, to ‘repulsion’ at the other extreme (see Table 1 and Table 3, as well as Frederick et al., 2014).

To further underline the link between attention and choice reversal, we also wished to investigate if it is possible to predict if a decoy actually induced a change in a subject’s preferences in a given matching trial in which a target was chosen, based solely on how the subject visually examined the available options. In other words, on the basis of how attention was distributed between the decoy, the target and the competitor, we would like to predict if the target has been selected because of or irrespective of the decoy, i.e. if the target would also have been chosen had the decoy been absent.

The reason why we thought that this might be possible is as follows. If the decoy was set inferior to the subject’s preferred option (i.e. there was no choice reversal), then it would have only reinforced the subject’s tendency to look at the chosen target bundle as the more attractive option. In contrast, if the target was the less preferred option (i.e. a choice reversal occurred), then the decoy would have artificially inflated attention to the target, but attention to the option that was not chosen might still be substantial due to it being the subject’s more preferred bundle. Thus, we would expect attention to the option that was not chosen to have been higher in case of choice reversal than in those cases when it does not occur, and this should make it possible to ‘diagnose’ choice reversals from eye-data.

Indeed, following a cross-validation procedure, we obtained an ‘out-of-sample’ classification accuracy that was significantly above chance. This further points to the role of

attention in choice reversal, since, given a set of options and an observed choice, the way in which attention was distributed is indicative of whether the choice in question has been affected by the decoy option. It is also a fact that could, in the future, be used in the evaluation of the effectiveness of decoys deployed as marketing tools. Similarly, or in further research of context effects.

Scope and Limitations

Despite the novelty of using eye-tracking and non-hypothetical choices to study the attraction effect, we must acknowledge certain limitations in the extent to which the results would generalize beyond the present experimental framework. In particular, our presentation of the choice trials as a spatial grid was different from both the abstract numerical and the pictorial presentation used in previous studies. We thought that the spatial grid might, from the subjects' point of view, resemble a real-world retail setting in which goods are arranged on shelves with similar products located close together. Nevertheless, one might argue that similarity measured as the distance in the space of product attributes is not the same as one between, say, a fresh vs. a spoiled apple (i.e., as in the studies with pictorial presentation). The fact that, in our setting, similarity is correlated with visual proximity could potentially cause artefacts, such as attention switching from decoy to target merely due to the ease of transferring gaze over a short distance, or indeed result in eye fixations on the decoy being incorrectly registered as ones on a similar and spatially close target. Fortunately, the effect we have found is in the opposite direction, with more attention on the target registered when the decoy is further away from it. Nevertheless, future research might verify if it would still persist if the choice options were presented in a more conventional manner, which would have the additional advantage of facilitating comparisons with previous literature.

A separate issue is the within-subjects design, and the fact that subjects would first choose without and then with a decoy being present. This was to identify their ‘true’ preference, undistorted by any current or previous exposure to decoys. However, it may have been that the initial binary choice in some way influenced the choice in the later, matching trial, despite the presence of the distractor tasks.

Similarly, the subjects may have noticed a pattern in the matching trials, where one of the options (decoy) was always inferior compared to the target, potentially generating experimenter demand effects (though the chance of this happening is reduced by the fact that the choices were incentivized, and whether the experimenter would demand a choice of the target or the competitor could not have been apparent to subjects). These problems could be addressed in future research, perhaps via more unobtrusive, indirect ways of establishing preferences. Our results on detecting choice reversals from eye-data could provide some guidance as to how this might be achieved.

Overall, our results are consistent with and shed light on the abstract vs. pictorial discrepancy reported by previous studies, which may indeed be due to the abstract representation of the choice options making the inferiority relationship between decoy and target salient, and the pictorial one highlighting their similarity instead, thus weakening the attraction effect. On the other hand, the fact that inferiority rather than similarity is crucial for the attentional spotlight to be cast by the decoy on the target can be contrasted with what is postulated by existing theories (Roe et al., 2001; Trueblood et al., 2014, and others), which generally assume that similarity is required for inferiority of the decoy to have an effect. Because of both the novelty and limitations of our experiment design discussed above, it is too early to say if the assumptions about the role of attention present in existing accounts of the attraction effect should be revised.

At the same time, the effect was, in the past, demonstrated in various and often unusual settings (e.g. Shafir, Waite, & Smith, 2002; J. Trueblood, Brown, Heathcote, & Busemeyer, 2013). In line with this tradition, our work can be seen as extending the set of circumstances in which attraction occurs, as well as documenting the underlying attentional patterns.

Conclusions

The present study was the first one to investigate the attentional correlates of decoy-induced choice reversals on an individual-trial level, and one of the very few studies of the attraction effect involving non-hypothetical choices. Combining a repeated-measures design with a mixed model analysis of the data allowed for a precise identification of how the attributes of the decoy vis-à-vis those of the target influence the transfer of attention towards the latter and the likelihood of a choice reversal.

In particular, we found that a decoy does indeed draw attention towards its target and away from the competitor, but that this effect is reduced as the decoy becomes more similar and hence less strongly inferior relative to the target. We also found that the same circumstances also reduce the choice reversal likelihood.

Our results suggest that it is the inferiority, rather than similarity of the decoy to target which drives the attraction effect. This could help explain the discrepancy of results in studies with abstract vs. pictorial representation of the choice options, because the former makes inferiority salient, while the latter tends to emphasize similarity.

To further underline the link between choice reversal and attention, we showed that, based on how a person looked at the available options, it is possible to predict if the presence of the decoy influenced the observed choice. This suggests that eye-data could be used in the assessment of marketing strategies and in the further research of context effects.

569

570

Figure 1. An example choice-problem.

571
572 Figure 2. Example choice screen shown to subjects (subjects do not see the red captions); the
573 placement of canteen vs. supermarket voucher values within the disks and in the X-Y space was
574 flipped for half of the subjects.

575

Figure 3. Example distractor task screen shown to subjects

Figure 4. Illustration of the estimated regression model of attention reversal. In the example shown in the left panel, the top-left of the two bundles (in red) is the ‘preferred’ one (chosen in the initial trial). The coloured circles represent the potential locations of decoy bundles targeting the ‘not-preferred’, bottom-right bundle (in black). The colour of each circle represents the value of attention reversal, i.e. the extent to which attention is transferred towards the ‘not-preferred’ bundle (in the direction indicated by the arrow) in the matching trial. The value of attention reversal is obtained from the estimated regression for the value of proximity-to-target calculated for the given decoy location and target-preferred = 0. In the right panel, the analogous attention reversal is shown in the opposite case of the bottom-right bundle having been chosen in the initial trial (in this case, target-preferred = 1).

591 Table 1. Average attention reversal (across all subjects and trials) depending on the values of
 592 ‘target-preferred’ (1 = decoy inferior to the option chosen in the initial trial) and ‘proximity-to-
 593 target’ (relative to the competitor).

average attention reversal		
proximity-to-target	target-preferred	
	0	1
$(-\infty, 0]$	.792	.142
$(0, 2]$	.566	.005
$(2, 3]$	.508	-.009
$(3, 4]$	.463	.192
$(4, 6]$	.259	.430
$(6, \infty)$	.126	.389

594

Table 2. Coefficient estimates of a mixed-effects model of attention reversal between the matching and initial trial, modeled as a function of whether the target was set to the option preferred in the initial trial and of the proximity/similarity of the decoy to the target relative to the competitor.

attention reversal between matched trials (N = 1443)						
fixed effects						
	β	SE	t	p	95% CI	
					Lower	Upper
intercept	0.702	0.113	6.231	<.001*	0.481	0.924
target-preferred	-0.724	0.138	-5.264	<.001*	-0.994	-0.454
proximity-to-target	-0.082	0.026	-3.154	.002*	-0.133	-0.031
target-preferred *proximity-to-target	0.135	0.048	2.790	.006*	0.040	0.230
(*significant at $p < .05$)						
random effects						
	variance		correlation m.			
intercept	0.294					
target-preferred	0.342		-0.98			
proximity-to-target	0.008		-0.99 0.98			
target-preferred *proximity-to-target	0.056		0.84 -0.94 -0.84			

599 Table 3. The frequency of choice reversal (across all subjects and trials) depending on the values
 600 of ‘target-preferred’ and ‘proximity-to-target’.

frequency of choice reversal		
proximity-to-target	target-preferred	
	0	1
$(-\infty, 0]$	.385	.100
$(0, 2]$	.305	.128
$(2, 3]$	.209	.160
$(3, 4]$	.159	.227
$(4, 6]$	.128	.406
$(6, \infty)$	.100	.214

601

Table 4. Coefficient estimates of a mixed-effects model of the likelihood of choice reversal between the matching and initial trial, modeled as a function of whether the target was set to the option preferred in the initial trial and of the proximity/similarity of the decoy to the target relative to the competitor.

choice reversal between matched trials (N = 1443)						
	β	SE	t	p	95% CI	
					Lower	Upper
intercept	-0.369	0.241	-1.535	.125	-0.841	0.103
target-preferred	-1.801	0.305	-5.897	<.001*	-2.400	-1.202
proximity-to-target	-0.396	0.067	-5.888	<.001*	-0.529	-0.264
target-preferred *proximity-to-target	0.636	0.100	6.345	<.001*	0.440	0.833
(*significant at p < .05)						
random effects						
	variance		correlation m.			
intercept	1.277					
target-preferred	0.502		-0.96			
proximity-to-target	0.058		-0.50 0.71			
target-preferred *proximity-to-target	0.108		0.88 -0.98 -0.85			

607 Table 5. Coefficient estimates of a mixed-effects model of the likelihood of choice reversal
608 between the matching and initial trial, based on the same specification as the one in Table 4, but
609 with attention-reversal added as an independent variable.

choice reversal between matched trials						
	β	SE	t	p	95% CI	
					Lower	Upper
intercept	-1.932	0.303	-6.366	<.001*	-2.527	-1.337
target-preferred	-1.393	0.442	-3.154	.002*	-2.260	-0.527
proximity-to-target	-0.447	0.094	-4.777	<.001*	-0.630	-0.263
target-preferred *proximity-to-target	0.688	0.148	4.660	<.001*	0.398	0.977
attention-reversal	1.956	0.132	14.819	<.001*	1.697	2.215
(*significant at $p < .05$)						
random effects						
	variance	correlation m.				
intercept	3.035					
target-preferred	1.339	-0.87				
proximity-to-target	0.095	-0.46	0.54			
attention-reversal	0.186	-0.21	-0.28	-0.30		
target-preferred *proximity-to-target	0.242	0.81	-0.87	-0.87	0.23	

Table 6. Coefficient estimates of a mixed-effects logistic regression model of the likelihood of choice reversal between the matching and initial trial, for matching trials in which the target was chosen, modeled as a function of proportional attention (fixation time) to the competitor and the target in the matching trial.

choice reversal between matched trials						
	β	SE	t	p	95% CI	
					Lower	Upper
intercept	-2.792	1.102	-2.533	.012*	-4.955	-0.628
attention-to-competitor	8.085	2.338	3.458	.001*	3.495	12.674
attention-to-target	1.339	1.315	1.019	.309	-1.242	3.920
attention-to-competitor *attention-to-target	-6.935	3.530	-1.964	.048*	-13.869	-0.005
(*significant at $p < .05$)						

Methodological Detail Appendix

The stimulus presentation software was programmed in Wolfram Mathematica. Each subject was seated at a computer terminal, operating Microsoft Windows 8, with a 15.4-inch screen with resolution set to 1280x720, and a SensoMotoric Instruments RED250 mobile eye-tracking device attached underneath the screen and set to 250Hz frequency. Prior to the commencement of the study, we conducted a standard five-point semi-automatic calibration and validation procedure (the average deviation was below 0.5° for all subjects). Each trial was preceded by a fixation cross, and subjects chose their preferred choice option using keyboard or mouse. A headrest was used to stabilize the head position and ensure that the distance between the subject's eyes and the device was approximately 65cm. We used the SMI Vision high-speed fixation detection algorithm with standard settings (minimum fixation duration = 50ms, peak saccade velocity threshold $40^{\circ}/s$). All studies were approved by the local Faculty Research Ethics Committee.

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