Choice consistency and the attraction effect

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The attraction effect directly violates the consistency requirements necessary for rational choice, but so far it has attracted little attention. I present a laboratory experiment aimed at testing it and at disentangling some of its explanations using new manipulations. I find the attraction effect and I also uncover a 'range effect' that runs against it. This range effect lends support to recent theories based on focusing and salience.

Keywords: attraction effect, asymmetric dominance effect, decoy effect, range effect, risky choice, individual decision-making
JEL codes: C91, D03, D11, D80

1 Introduction

Economics requires choice to be consistent. Choice, however, has been shown to depend on supposedly irrelevant options, a phenomenon called a context effect. The most famous context effect is the *attraction effect*.[1] It directly attacks rational choice, so one would expect it to appear prominently in the economic literature. Instead the attraction effect is most often relegated to a supporting role, never under the spotlight but working either as an illustration[2] or as a motivation. For instance the attraction effect has recently

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[1] Sometimes referred to as the asymmetric dominance effect or, rather confusingly, the decoy effect.

[2] As is the case for Barbos (2010), Blavatskyy (2012), Masatlioglu and Uler (2013), Bordalo et al. (2013) and Gerasimou (2016)

motivated attempts to find weaker forms of consistency (e.g. Cherepanov et al., 2013; de Clippel and Eliaz, 2012; Manzini and Mariotti, 2012; Masatlioglu et al., 2012; Ok et al., 2015), but without further studies on the attraction effect it is not clear if consistency needs weakening in the first place.

Here I focus squarely on the attraction effect and present a carefully controlled, incentivised experiment aimed at testing and explaining it. The results show that the effect exists, but in a smaller magnitude than previously reported. The experiment also uses new manipulations to test explanations of the attraction effect. While doing so, I find a new effect running against it, the 'range effect', which lends support to contemporary theories of choice based on focusing and salience.

The attraction effect refers to the situation in which adding x' to a menu containing options x and y, when x' is dominated by x but not by y, increases the choice of x. x' is referred to as the asymmetrically dominated 'decoy'. The attraction effect was discovered more than 30 years ago by Huber et al. (1982) and is still an active research area (see the recent debate between Frederick et al., 2014; Huber et al., 2014; Simonson, 2014; Yang and Lynn, 2014). It has spawned an enormous literature in psychology and consumer research and has been observed in multiple settings, classically with consumer products (see Heath and Chatterjee, 1995, and Milberg et al., 2014, for reviews, as well as Gomez et al., 2016, for a recent example), but also with job candidates (Highhouse, 1996; Slaughter, 2007; Slaughter et al., 1999, among others), political issues (Herne, 1997), investment opportunities (Schwarzkopf, 2003), and in the contingent evaluation of environmental goods (Bateman et al., 2008). The roots of the attraction effect seem to go deep since it has been observed in inferential (Trueblood, 2012) and perceptual tasks (Crosetto and Gaudeul, 2016; Trueblood et al., 2013). It is not restricted to the laboratory: Pan et al. (1995) provide evidence of the influence of an attraction effect in the 1994 Illinois State primary election and the 1992 U.S. Presidential election. In a field experiment conducted in a local grocery store in the UK, Doyle et al. (1999) managed to increase the sales of the least-often-bought brand of baked beans thanks to an asymmetrically dominated decoy.[3] But, despite the number of studies outside economics, few use an incentive-compatible design: of the 52 reviewed by Lichters et al. (2015) only one does.

There are two ways of characterising the attraction effect: one, which I call 'Attraction Effect WARP', violates the Weak Axiom of Revealed Preference; the other, 'Attraction

[3] The attraction effect has even been observed with grey jays and honeybees (Shafir et al., 2002), slime moulds (Latty and Beekman, 2011) and rhesus macaques (Cohen and Santos, 2017; Parrish et al., 2015), which some researchers interpret as evidence of the ubiquitousness of the attraction effect.

Effect Chernoff', violates the Chernoff Condition.[4] Previous studies have conflated these two characterisations and have used them interchangeably, but they have different implications. As is known, the Weak Axiom of Revealed Preference is necessary and sufficient for the existence of a complete and transitive (rational) preference relation underlying choice, while the Chernoff condition is necessary for the existence of *any* preference relation. Hence observing Attraction Effect WARP means that people's choices cannot be explained by a rational preference relation, but a non-transitive one could. Observing Attraction Effect Chernoff, on the other hand, rules out all preference relations. Instead of focusing on one or the other, the experiment I designed tests both characterisations under the same conditions and combines within-and between-subject comparisons to further attack the problem from different angles. Since a choice function satisfying the Weak Axiom of Revealed Preference necessarily satisfies the Chernoff Condition but not the other way round, I further predict that Attraction Effect WARP will be more easily detectable than Attraction Effect Chernoff.

The results clearly demonstrate the reality of the attraction effect, and, as predicted, Attraction Effect WARP is more prevalent than Attraction Effect Chernoff. No one expects choice to be perfectly consistent, but inconsistency is generally thought to come from one of two sources: either a substantial amount of time has passed and preferences have changed, or framing effects are at play (Kahneman and Tversky, 1984; Tversky and Kahneman, 1986). None of these apply here: at most 15 minutes separate two choices, and framing is constant. Yet, the attraction effect is smaller than the one found in previous studies and concerns a minority of subjects.

Two explanations to the attraction effect have so far appeared in the literature. The first argues that adding decoys changes people's relative weighting of the attributes constituting the options. This *weights explanation* is assumed to be driven by a *negative range effect*: increasing the range of an attribute makes people weight this attribute *less*. If this interpretation is correct then increasing the attribute ranges even more should generate more negative range effect and thus more attraction effect. To test this prediction I create new decoys which double the attribute ranges compared to the typical decoys. The results show that these new decoys do not cause more attraction effect and so reject the weights explanation.

The second way of explaining the attraction effect is that adding a decoy changes *how* people choose. As its name suggests, an asymmetrically dominated decoy is dominated by only one option and so, if people have weak or imprecise preference, they might feel

[4] Also called Sen's α (Sen, 1969), basic contraction consistency (Sen, 1977) or the independence of irrelevant alternatives (Nash, 1950).

compelled to choose the dominating option. Thus this *process explanation* hinges on the decoys being asymmetrically dominated and removing the asymmetric dominance should eliminate the attraction effect. I test this by introducing a second class of new decoys which also double the attribute ranges but are *symmetrically* dominated. Because they double the ranges the weights explanation predicts more attraction effect, just like the previous new decoys. But because they are symmetrically dominated, the process explanation predicts no attraction effect.

In fact they trigger, not more, not none, but a *negative* attraction effect. This negative attraction effect results from a *positive range effect*: increasing the range of an attribute makes people weight it, not less, but *more*. It further invalidates the weights explanation and runs against the attraction effect. As far as I know this effect was only hinted at in previous research in psychology (Fischer, 1995; Goldstein, 1990; Mellers and Cooke, 1994; von Nitzsch and Weber, 1993; Wedell, 1998; Wedell and Pettibone, 1996) and I am the first to report it in an incentivised experiment in economics. It also gives support to recent focusing and salience theories (Bordalo et al., 2012, 2013; Cunningham, 2013; Kőszegi and Szeidl, 2013) which build on the idea that people focus more on attributes that stand out.

I present a simple model in which preferences depend on the presence of asymmetrically dominated decoys and on attribute ranges. I estimate this model using a mixed logit model, which controls for order effect, correlation between choice tasks and preference heterogeneity, and confirm the previous results. The model shows that, while the majority of subjects exhibit the positive range effect, about 30% of them exhibit the negative one. For this minority range effect and attraction effect go hand in hand, so they should exhibit more attraction effect. I confirm this prediction and show that their attraction effect is close to what was previously reported in the attraction effect literature.

As mentioned earlier few studies in economics focus on the attraction effect. The one most closely related to mine is Herne (1999). Compared to her experiment the main difference is the use of new decoys to tease apart the explanations to the attraction effect. The present experiment, thanks to higher incentives, gambles with different expected values, and a more concrete and transparent procedure, also constitutes a more robust test of the attraction effect. More details on the similarities and the differences are provided in the main text. Herne herself built upon Wedell (1991), a non-incentivised study from psychology, and so my study can be seen as a logical continuation of this line of research. Kroll and Vogt (2012) also study the attraction effect but they focus on its impact on certainty equivalents. Crosetto and Gaudeul (2016), following Trueblood et al. (2013), study the effect, not with gambles, but in a perceptual task, and demonstrate the importance of using options with different expected values, a recommendation I follow.

2 Attraction effect and economic theory

The attraction effect starts with the choice between options defined by two attributes such that no option outright dominates. Denote these options by $x = (x_1, x_2)$ and $y = (y_1, y_2)$ with $x_1 > y_1$ and $y_2 > x_2$. The attraction effect occurs following the introduction of an asymmetrically dominated decoy, an additional option dominated by only one of the two original options. Throughout this paper I will use superscripts to denote the decoys. For example, x', which I already mentioned in the introduction, is the asymmetrically dominated decoy of x: it is dominated by x but not by y.

Loosely speaking the attraction effect occurs when introducing x' makes people choose x more often, and y', y. Two ways of characterising the attraction effect exist. The first one, used for example by Herne (1999), looks at the combined effect of x' and y'. Let c be the choice function:

Attraction Effect WARP. $c\Big(\{x, y, x'\}\Big) = x$ *and* $c\Big(\{x, y, y'\}\Big) = y$.

As the name implies, Attraction Effect WARP violates the most famous consistency requirement: the Weak Axiom of Revealed Preference. Denote by X the set of options, $\mathcal{B}$ the set of non-empty subsets of X and $A, B \in \mathcal{B}$ the menus:[5]

Weak Axiom of Revealed Preference. *For all* $A, B \in \mathcal{B}$ *and all* $x, y \in X$*, if* $x, y \in A \cap B$ *and if* $x \in c(A)$ *and* $y \in c(B)$*, then* $x \in c(B)$*.*

In words, if x is sometimes chosen from A when y is available, then when y is chosen in B although x is available, x is also chosen.

The second way of characterising the attraction effect, more common in consumer research, focuses on the effect of one decoy at a time, and so is split into two parts:

Attraction Effect Chernoff.

1. $c\Big(\{x, y\}\Big) = x$ *and* $c\Big(\{x, y, y'\}\Big) = y$
2. $c\Big(\{x, y\}\Big) = y$ *and* $c\Big(\{x, y, x'\}\Big) = x$

[5] The following is from Mas-Colell et al. (1995), but note that this particular form of WARP is called the Houthaker axiom by Kreps (1988).

This characterisation of the attraction effect violates the Chernoff Condition (1954):

Chernoff Condition. *For all $A, B \in \mathcal{B}$, if $x \in B \subset A$ and $x \in c(A)$, then $x \in c(B)$.*

In words, if x is chosen in the large set, then it is also chosen in the small set. Sen's famous paraphrase is: if the world champion in some game is a Pakistani, then he must also be the champion of Pakistan.

Consistency requirements allow to infer the existence of a preference relation $\succsim$ that underlies observed choice c. In this case it is said the preference relation rationalises[6] c: $\forall B \in \mathcal{B}\ c(B) = c(B, \succsim) = \{x \in B : x \succsim y\ \forall y \in B\}$. WARP and the Chernoff Condition give rise to different types of preference relation: WARP is necessary and sufficient for $\succsim$ to be complete and transitive, that is, *rational* (Mas-Colell et al., 1995, Proposition 1.D.1 and 1.D.2, pp. 12-13), while the Chernoff Condition is necessary for the existence of *any* preference relation, rational or not (Sen, 1969, Lemma 2, p. 384). WARP implies the Chernoff Condition but not the other way round: the Chernoff Condition needs to be complemented by Sen's β to imply WARP (Sen, 1971, T.8 and Corollary, p. 314). So, the Chernoff Condition is weaker and more general than WARP and its violation should be observed less often: there should be more people with non-rational preferences than people without preferences at all.

Putting everything together:

- Since Attraction Effect WARP violates the Weak Axiom of Revealed Preference, if Attraction Effect WARP is observed then no rational preference relation can rationalise choice;

- Since Attraction Effect Chernoff violates the Chernoff Condition, if Attraction Effect Chernoff is observed then no preference relation, rational or not, can rationalise choice;

- Since the Weak Axiom of Revealed Preference implies the Chernoff Condition, we can expect to observe more Attraction Effect WARP than Attraction Effect Chernoff.

In other words, Attraction Effect WARP leaves the door open for, say, a non-transitive preference relation to rationalise choice. Attraction Effect Chernoff closes that door by ruling out all preference relations.

Now that we know what is the attraction effect and what it implies, we can look at how it can be explained.

[6] Sen (1971) calls 'normal choice function' a function that can be rationalised.

3 Explanations to the attraction effect

Instead on relying on consumption goods such as cars, beers or TV sets to test the attraction effect, as is traditionally done in consumer research, I follow Wedell (1991) and Herne (1999) and study the effect with gambles, for a variety of reasons. Experiments using, say, cars, have to restrict on two attributes and describe the cars in terms of these two attributes only, even if in principle cars could be described with an infinity of attributes. Gambles circumvent this issue by having two natural attributes: probability and money. They are also easier to implement and incentivise since subjects can play their chosen gamble at the end of the experiment and be paid accordingly. Finally, one can see probabilities as standing for a general measure of quality and so extrapolate the results to other domains.[7]

To present the experimental design, I will rely throughout on Figure 1, which depicts the gambles and the different classes of decoys used. The experiment focuses on simple gambles offering a probability p of winning £x and a probability $1-p$ of winning £0, denoted by (x,p). In the Figure probabilities p are on the x-axis, and winning amounts x on the y-axis. Following the previous literature I focus on two types of gambles: $\omega_p = (x_p, p_p)$ and $\omega_£ = (x_£, p_£)$. As can be seen in the Figure, ω_p is better in the **p**robability attribute, $p_p > p_£$, while $\omega_£$ is better in the **£**x attribute, $x_£ > x_p$. These are akin to the P-bets and $-bets found in the literature on preference reversals between choice and valuation (Cubitt et al., 2004; Plott and Grether, 1979; Tversky et al., 1990). The asymmetrically dominated decoys testing the classical attraction effect, also depicted, are ω'_p and $\omega'_£$.

Over the years, researchers in psychology and consumer research have proposed many explanations to the attraction effect, which can be grouped into two categories (Herne, 1996; Köhler, 2007; Wedell, 1991). The first, the oldest one,[8] is a preference-based explanation: it argues that adding decoys changes the weights people attach to the attributes. For example, according to this *weights explanation* people choose ω_p following the introduction of ω'_p because they weight less the money attribute x. They weight it less because, as the explanation goes, the attribute range changes: Figure 1 shows that ω'_p increases the range of money from Δ_x to Δ'_x. Thus the attraction effect as explained by the weights explanation arises from a *negative range effect*, according to which increasing an attribute range makes people weight less this particular attribute.

[7] However, note that probabilities have natural upper and lower bounds while quality has none. I thank Kaisa Herne for this remark

[8] It was first proposed by Huber et al. (1982) and is based on Parducci's (1974) range-frequency theory. Simonson and Tversky (1992) and Tversky and Simonson (1993) have a similar explanation.

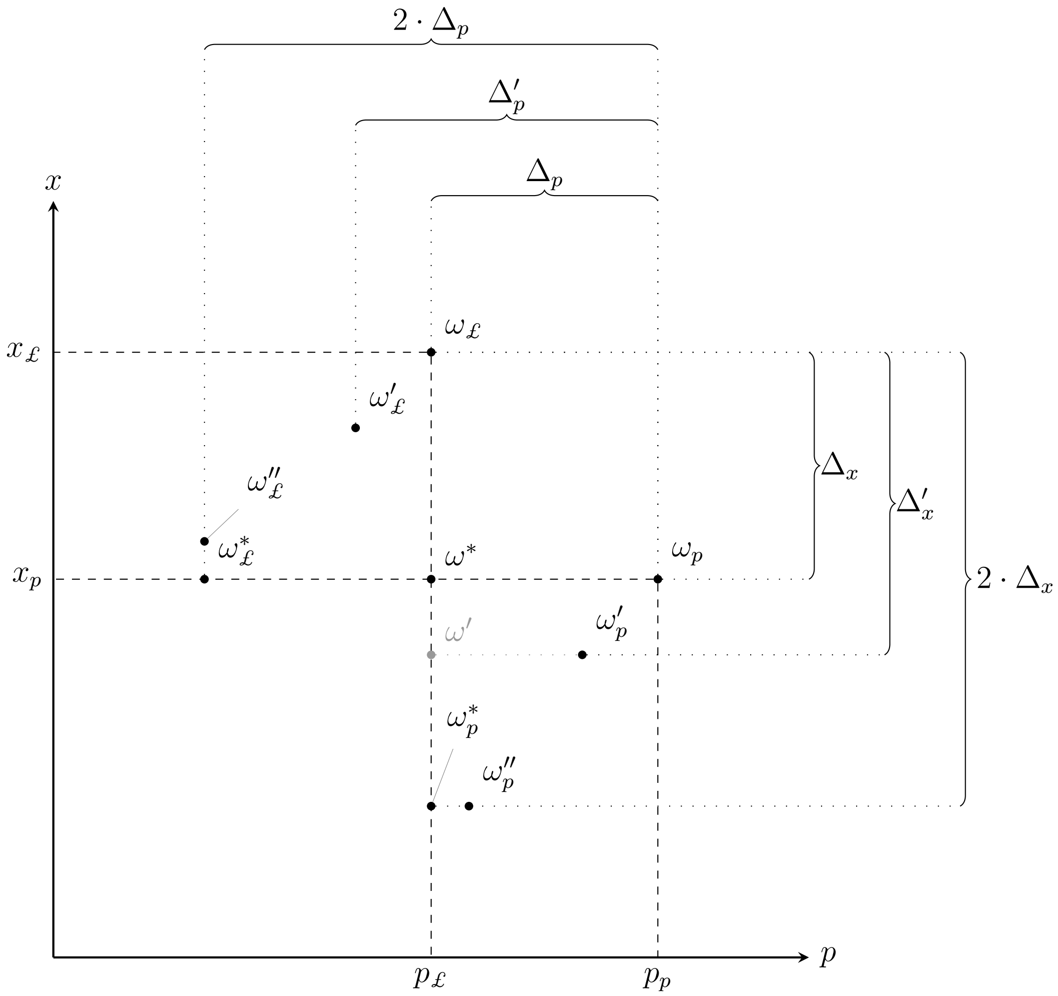

Figure 1: Decoys used to test the attraction effect and its explanations.

If this weights explanation is correct then increasing even more the ranges should cause more negative range effect and so more attraction effect. To test this prediction I created the decoys ω''_p and $\omega''_£$. As can be seen in Figure 1, these new decoys double the ranges, from Δ_x and Δ_p to $2 \cdot \Delta_x$ and $2 \cdot \Delta_p$, and so should cause more attraction effect due to the negative range effect. They also test one of the findings of Heath and Chatterjee's (1995) meta-analysis: the greater the range extension, the more pronounced the attraction effect.

The second category of explanations is a heuristic-based explanation: it argues that adding a decoy changes *how* people make a choice. This *process explanation* hinges on the decoys being asymmetrically dominated. For example, ω_p dominates ω'_p but $\omega_£$ does not; one could then feel that ω'_p gives good reason to choose ω_p.[9] So, the process

[9]This is Simonson's (1989) 'choice based on reasons' approach. For a similar reasoning, see Ariely and

explanation explains the attraction effect as a change of decision process triggered by the introduction of an asymmetrically dominated option.

To test for this explanation, I remove the asymmetric dominance from ω_p'' and $\omega_£''$ to create ω_p^* and $\omega_£^*$. As Figure 1 shows, ω_p^* and $\omega_£^*$ have the same range extension as ω_p'' and $\omega_£''$, at $2 \cdot \Delta_x$ and $2 \cdot \Delta_p$, so the weights explanation predicts the same attraction effect. On the other hand, since ω_p^* and $\omega_£^*$ are *symmetrically* dominated the process explanation predicts that the attraction effect will disappear. In other words, if the attraction effect disappears the process explanation can be ruled out; if it holds it has to come from the weights explanation alone. For this reason ω_p^* and $\omega_£^*$ are the important decoys that allow me to discriminate between the two explanations.

Wedell (1991, Experiment 2) followed a similar approach and used the decoy ω' (also represented in Figure 1) which removes the asymmetric dominance from ω_p'. He found that adding ω' has no effect and so concluded against the weights explanation, which subsequent studies confirmed (Wedell, 1998; Wedell and Pettibone, 1996). His design, however, did not give the weights explanation much chance to succeed. For example, it used $\omega_1 = (\$20, 0.5)$, $\omega_2 = (\$33, 0.3)$ and $\omega' = (\$18, 0.3)$. With these, the range of winning amounts increases from $\Delta_x = 33 - 20 = \$13$ to $\Delta_x' = 33 - 18 = \$15$, so the range extension is minimal. The weights explanation might work but only for greater range extensions, hence why I am doubling the ranges.

Finally, I use the neutral decoy ω^* to test for the mere effect of introducing an option. As we see in Figure 1, ω^* does not increase a range nor is asymmetrically dominated, so both explanations predict that it will have no impact.

To summarise, I use four classes of decoys, each asking a different question:

- ω_p' and $\omega_£'$ test for the classical attraction effect.
- ω_p'' and $\omega_£''$ keep the asymmetric dominance but double the attribute ranges. The weights explanation predicts that we will observe a stronger attraction effect due to the negative range effect.
- ω_p^* and $\omega_£^*$ also double the attribute ranges but remove the asymmetric dominance. The weights explanation predicts that we will observe the same attraction effect compared to the previous decoys, while the process explanation predicts that the attraction effect will disappear.
- ω^* does not increase attribute ranges and is symmetrically dominated, so both explanations predict that it will have no effect.

Wallsten (1995) and Hedgcock and Rao (2009).

The next Section presents the experimental design implementing these decoys in the laboratory.

4 Experimental design

4.1 Parameter sets, between- and within-subject comparisons

I started by creating 14 sets of gambles. Most studies on the attraction effect have used options with the same expected value to ensure indifference. As pointed out by Frederick et al. (2014) and Crosetto and Gaudeul (2016) this creates a strange situation where not only decoys but *anything* could tip a subject into choosing one or the other option. Since previous research has overwhelmingly demonstrated the prevalence of the attraction effect I decided to focus on the situation where the options are *not* of the same expected value to test the robustness of the effect. Consequently, in each set of gambles the expected value of $\omega_{\pounds}$ is 20% higher than the one of ω_p. I also used higher stakes than usual: for the first 11 sets, the expected values of ω_1 and ω_2 are approximately £5.8 and £7; for the remaining 3 sets, they are £10 and £12. By contrast, Herne's (1999) gambles were all of the same expected value of 30 Finnmarks, which was approximately £3.3 in 1999.[10]

Each set accommodates all decoys mentioned in the previous section to ensure that all sets have the same underlying structure and so can be compared. Accommodating ω_p^* and $\omega_{\pounds}^*$ imposes the most restrictions. For example, $\omega_p = (\pounds 7.2, 0.8)$ and $\omega_{\pounds} = (\pounds 23, 0.3)$ cannot be part of a valid set: the probability range is $\Delta_p = 0.8 - 0.3 = 0.5$ and it is impossible to introduce a $\omega_{\pounds}^*$ that doubles it. Table 1 presents the resulting 14 sets.

Then, of the first 11 low-stake sets (sets a to k), I randomly selected 3 to study the decoys $\{\omega_p', \omega_{\pounds}'\}$, 3 to study $\{\omega_p'', \omega_{\pounds}''\}$ and, since these are the most important ones, 5 to study $\{\omega_p^*, \omega_{\pounds}^*\}$, making sure that the sets assigned to a class of decoys were not too similar. I also randomly assigned one of the 3 remaining high-stake sets to each class.

The experiment is setup to study Attraction Effect WARP within- and between-subject, and Attraction Effect Chernoff only between-subject. Within-subject designs have more statistical power, are less noisy, and are more natural when one wants to study preferences (Charness et al., 2012). But they are also more prone to elicit spurious effects due to sensitisation (Greenwald, 1976) or even experimenter demand (Zizzo, 2010). Experimenter demand effects are especially a problem for Attraction Effect Chernoff: since it requires to add a single, asymmetrically dominated option to the choice between two original options, it signals what the experiment is about and a subject can easily find

[10]Source: `http://www.xe.com/currencytables/?from=FIM&date=1999-08-01`

Table 1: Parameter sets.

Set	ω_p		$\omega_£$		ω^*		ω'_p		$\omega'_£$		ω''_p		$\omega''_£$		ω^*_p		$\omega^*_£$	
	p_p	x_p	$p_£$	$x_£$	p^*	x^*	p'_p	x'_p	$p'_£$	$x'_£$	p''_p	x''_p	$p''_£$	$x''_£$	p^*_p	x^*_p	$p^*_£$	$x^*_£$
a	0.8	7	0.55	12.5	0.55	7	0.75	6	0.5	11.5	0.6	1.5	0.3	8	0.55	1.5	0.3	7
b	0.75	7.5	0.55	12.5	0.55	7.5	0.7	6.5	0.5	11.5	0.6	2.5	0.35	8.5	0.55	2.5	0.35	7.5
c	0.75	7.5	0.5	14	0.5	7.5	0.7	6.5	0.45	13	0.55	1	0.25	8.5	0.5	1	0.25	7.5
d	0.7	8	0.5	14	0.5	8	0.65	7	0.45	13	0.55	2	0.3	9	0.5	2	0.3	8
e	0.7	8	0.45	15.5	0.45	8	0.65	7	0.4	14.5	0.5	0.5	0.2	9	0.45	0.5	0.2	8
f	0.65	8.5	0.5	14	0.5	8.5	0.6	7.5	0.45	13	0.55	3	0.35	9.5	0.5	3	0.35	8.5
g	0.65	8.5	0.45	15.5	0.45	8.5	0.6	7.5	0.4	14.5	0.5	1.5	0.25	9.5	0.45	1.5	0.25	8.5
h	0.6	9.5	0.5	14	0.5	9.5	0.55	8.5	0.45	13	0.55	5	0.4	10.5	0.5	5	0.4	9.5
i	0.6	9.5	0.45	15.5	0.45	9.5	0.55	8.5	0.4	14.5	0.5	3.5	0.3	10.5	0.45	3.5	0.3	9.5
j	0.6	9.5	0.4	17	0.4	9.5	0.55	8.5	0.35	16	0.45	2	0.2	10.5	0.4	2	0.2	9.5
k	0.5	11.5	0.3	22.5	0.3	11.5	0.45	10.5	0.25	21.5	0.35	0.5	0.1	12.5	0.3	0.5	0.1	11.5
l	0.75	13.5	0.5	25	0.5	13.5	0.7	12.5	0.45	24	0.55	2	0.25	14.5	0.5	2	0.25	13.5
m	0.7	14.5	0.45	27.5	0.45	14.5	0.65	13.5	0.4	26.5	0.5	1.5	0.2	15.5	0.45	1.5	0.2	14.5
n	0.65	15.5	0.5	24.5	0.5	15.5	0.6	14.5	0.45	23.5	0.55	6.5	0.35	16.5	0.5	6.5	0.35	15.5

Note. The gambles not used in the experiment have been greyed out.

out what is expected from her. For this reason I am studying Attraction Effect Chernoff only between-subject. Note that Wedell (1991) and Herne (1999) only studied Attraction Effect WARP within-subject, while most studies in psychology and consumer research only studied Attraction Effect Chernoff between-subject. In contrast the combination of the two approaches allows me to study the effect from two angles, which is one of the recommendations of Charness et al. (2012). And, if the effect were to appear only in one context, I would be suspicious of the reality of the effect.

Table 2 describes how I combined the two types of attraction effect and within- and between-subject comparisons in the same experiment. As can be seen in the Table, subjects are split into 4 groups. All subjects encounter the 14 parameter sets in the same order in the first booklet but they see different decoys depending on their group. For example, the first line of the Table corresponds to parameter set g. Subjects in the first group choose between ω_p and $\omega_£$; while subjects in the second, third and fourth groups have the decoys ω^*, ω^*_p and $\omega^*_£$ added to their menu. Comparing Group 1 and 3, and Group 1 and 4, addresses between-subject Attraction Effect Chernoff, while comparing Group 3 and 4 addresses between-subject Attraction Effect WARP. The menus $\{\omega_p, \omega_£\}$ and $\{\omega_p, \omega_£, \omega^*\}$ act as fillers between parameter sets so that subjects: *(a)* do not face the same class of decoy twice in a row; *(b)* do not face decoys favouring the same option twice in a row.

Subjects face again the 14 parameter sets in the second decision booklet (second part of Table 2) but with different decoys. Keeping the example of parameter set g, subjects

Table 2: Procedure of the experiment.

Set	Group 1	Group 2	Group 3	Group 4
		Booklet 1		
g	$\{\omega_p, \omega_£\}$	$+\omega^*$	$+\omega_p^*$	$+\omega_£^*$
c	$+\omega_p^*$	$+\omega_£^*$	$\{\omega_p, \omega_£\}$	$+\omega^*$
f	$+\omega^*$	$\{\omega_p, \omega_£\}$	$+\omega_£'$	$+\omega_p'$
k	$+\omega_£'$	$+\omega_p'$	$+\omega^*$	$\{\omega_p, \omega_£\}$
j	$\{\omega_p, \omega_£\}$	$+\omega^*$	$+\omega_p''$	$+\omega_£''$
m	$+\omega_p''$	$+\omega_£''$	$\{\omega_p, \omega_£\}$	$+\omega^*$
b	$+\omega^*$	$\{\omega_p, \omega_£\}$	$+\omega_£^*$	$+\omega_p^*$
h	$+\omega_£^*$	$+\omega_p^*$	$+\omega^*$	$\{\omega_p, \omega_£\}$
a	$\{\omega_p, \omega_£\}$	$+\omega^*$	$+\omega_p'$	$+\omega_£'$
n	$+\omega_p'$	$+\omega_£'$	$\{\omega_p, \omega_£\}$	$+\omega^*$
i	$+\omega^*$	$\{\omega_p, \omega_£\}$	$+\omega_£''$	$+\omega_p''$
e	$+\omega_£''$	$+\omega_p''$	$+\omega^*$	$\{\omega_p, \omega_£\}$
d	$\{\omega_p, \omega_£\}$	$+\omega^*$	$+\omega_p^*$	$+\omega_£^*$
l	$+\omega_p^*$	$+\omega_£^*$	$\{\omega_p, \omega_£\}$	$+\omega^*$
		Booklet 2		
g	$+\omega^*$	$\{\omega_p, \omega_£\}$	$+\omega_£^*$	$+\omega_p^*$
c	$+\omega_£^*$	$+\omega_p^*$	$+\omega^*$	$\{\omega_p, \omega_£\}$
f	$\{\omega_p, \omega_£\}$	$+\omega^*$	$+\omega_p'$	$+\omega_£'$
k	$+\omega_p'$	$+\omega_£'$	$\{\omega_p, \omega_£\}$	$+\omega^*$
j	$+\omega^*$	$\{\omega_p, \omega_£\}$	$+\omega_£''$	$+\omega_p''$
m	$+\omega_£''$	$+\omega_p''$	$+\omega^*$	$\{\omega_p, \omega_£\}$
b	$\{\omega_p, \omega_£\}$	$+\omega^*$	$+\omega_p^*$	$+\omega_£^*$
h	$+\omega_p^*$	$+\omega_£^*$	$\{\omega_p, \omega_£\}$	$+\omega^*$
a	$+\omega^*$	$\{\omega_p, \omega_£\}$	$+\omega_£'$	$+\omega_p'$
n	$+\omega_£'$	$+\omega_p'$	$+\omega^*$	$\{\omega_p, \omega_£\}$
i	$\{\omega_p, \omega_£\}$	$+\omega^*$	$+\omega_p''$	$+\omega_£''$
e	$+\omega_p''$	$+\omega_£''$	$\{\omega_p, \omega_£\}$	$+\omega^*$
d	$+\omega^*$	$\{\omega_p, \omega_£\}$	$+\omega_£^*$	$+\omega_p^*$
l	$+\omega_£^*$	$+\omega_p^*$	$+\omega^*$	$\{\omega_p, \omega_£\}$

Note. $+\omega^*$: ω^* added to $\{\omega_p, \omega_£\}$ to form $\{\omega_p, \omega_£, \omega^*\}$.

in Group 3 who faced the menu $\{\omega_p, \omega_£, \omega_p^*\}$ in the first booklet face $\{\omega_p, \omega_£, \omega_£^*\}$ in the second booklet, and the the other way round for subjects in Group 4. Comparing the choices across booklets for a given parameter set addresses within-subject Attraction Effect WARP. A consequence of this design is that half of the subjects see the decoy related to ω_p first (ω_p^* in the example) while the others see the decoy related to $\omega_£$ first ($\omega_£^*$), so the design also allows me to study the directionality of within-subject Attraction Effect WARP. Previous studies, on the other hand, studied the effect only in one direction for a given parameter set.

4.2 Procedure and incentives

To achieve concreteness the experiment made use of pairs of 10-sided dice to describe and play the gambles. All subjects had the dice on their desk throughout the experiment, they were encouraged to examine them and they knew that these would be the dice used to play their chosen gamble at the end of the experiment. The choice tasks themselves also referred to the dice (see Appendix A.1 for a sample). By contrast, previous experiments on the attraction effect using gambles, such as Herne (1999), relied on a random number generator on the computer and described the probabilities in abstract terms.

The experiment was incentivised using the PRINCE mechanism (Johnson et al., 2015). This recently developed mechanism adds transparency to the traditional random incentive system by asking subjects entering the laboratory to draw a sealed envelope that contains a piece of paper describing the entire choice task (of the 28 they face in the experiment) that will matter to determine their earnings. At the end of the experiment the subject and the experimenter open the envelope and flip through the booklets to find the task described on the piece of paper. The subject then plays the gamble she has chosen in this particular choice task and is paid accordingly, plus a show-up fee. Appendix A.2 details exactly how the experiment was conducted and how PRINCE was implemented.

Finally, the instructions (see Appendix A.3) featured detailed examples, none using the gambles that the subjects would encounter in the experiment, and control questions.

5 Results

The experiment took place across five sessions between the end of April and the beginning of June 2016 at the CeDEx laboratory in Nottingham. 207 subjects were recruited randomly using ORSEE (Greiner, 2015). A session lasted about 1 hour for an average payment of £11.37 (SD = £7.43). Each subject made 28 choices (14 in each booklet) and two subjects left a task blank, which leaves 5794 choices to exploit.

Across the whole experiments subjects chose decoys only 10 times, and about 80% chose the same option in both booklets. So, even if we observe the attraction effect, keep in mind that most subjects behaved rationally and were consistent. In what follows I will not mention decoy choices and I will focus on inconsistent patterns only.

Experiments on the attraction effect rarely allow subjects to express indifference, and the present one is no exception. Consequently when a subject chooses, say, ω_p in $\{\omega_p, \omega_£, \omega'_p\}$ in the first booklet and $\omega_£$ in $\{\omega_p, \omega_£, \omega'_£\}$ in the second booklet all we know is that $\omega_p \in c\Big(\{\omega_p, \omega_£, \omega'_p\}\Big)$ and $\omega_£ \in c\Big(\{\omega_p, \omega_£, \omega'_£\}\Big)$, which by itself is not inconsistent. Note that under the incentive scheme the subject making these choices has the same probability of receiving ω_p or $\omega_£$ at the end of the experiment, so she must be indifferent between ω_p and $\omega_£$. But if she is indifferent, the opposite pattern, choosing $\omega_£$ in $\{\omega_p, \omega_£, \omega'_p\}$ and ω_p in $\{\omega_p, \omega_£, \omega'_£\}$, must be equally likely. What *is* inconsistent, then, is observing that the proportion of subjects exhibiting one pattern is greater than the other.[11] The same reasoning applies when $\{\omega_p, \omega_£, \omega'_£\}$ appears in the first booklet and $\{\omega_p, \omega_£, \omega'_p\}$ in the second booklet as well as for the other decoys.

So, denoting by $\tilde{\omega}_i$ the decoy associated with ω_i, $i, j \in \{p, £\}$ $i \neq j$, and $\Pr(\cdot)$ the proportion, within-subject Attraction Effect WARP is characterised by

$$\begin{aligned} &\Pr\left(\omega_i \in c\Big(\{\omega_p, \omega_£, \tilde{\omega}_i\}\Big) \text{ and } \omega_j \in c\Big(\{\omega_p, \omega_£, \tilde{\omega}_j\}\Big)\right) \\ &- \Pr\left(\omega_j \in c\Big(\{\omega_p, \omega_£, \tilde{\omega}_i\}\Big) \text{ and } \omega_i \in c\Big(\{\omega_p, \omega_£, \tilde{\omega}_j\}\Big)\right) > 0, \end{aligned} \tag{1}$$

which I will test using a one-sided McNemar test.

Between-subjects attraction effects at the aggregate level are easier to characterise: they happen when the proportion of subjects choosing a particular option increases. Using the same notation as before, between-subject Attraction Effect WARP is characterised by

$$\Pr\left(\omega_i \in c\Big(\{\omega_p, \omega_£, \tilde{\omega}_i\}\Big)\right) - \Pr\left(\omega_i \in c\Big(\{\omega_p, \omega_£, \tilde{\omega}_j\}\Big)\right) > 0, \tag{2}$$

and between-subject Attraction Effect Chernoff by

$$\Pr\left(\omega_i \in c\Big(\{\omega_p, \omega_£, \tilde{\omega}_i\}\Big)\right) - \Pr\left(\omega_i \in c\Big(\{\omega_p, \omega_£\}\Big)\right) > 0, \tag{3}$$

both tested using a one-sided χ^2 test.

[11] Cubitt et al. (2004) use the same argument in the context of preference reversals.

Figure 2 reports the aggregate results of the experiment. I will comment on parameter-set irregularities when appropriate. Disaggregated and detailed results can be found in Appendix B.

5.1 There is a (small) attraction effect

I start with the classical attraction effect, using the decoys ω'_p and $\omega'_£$. The top-left graph of Figure 2 focuses on within-subject Attraction Effect WARP, when ω'_p is seen first ($\omega'_p \rightarrow \omega'_£$, first row) or when $\omega'_£$ is seen first ($\omega'_£ \rightarrow \omega'_p$, second row). We see that the attraction effect is significant in both cases so the experiment replicates the results from Wedell (1991) and Herne (1999); but note that when $\omega'_£$ is seen first the effect is in the right direction for all parameter sets but significant in only one. The top-left graph of Figure 2 shows that Attraction Effect WARP carries-over to between-subject comparisons.

Moving to Attraction Effect Chernoff, the bottom graph of Figure 2 shows that the effect appears with ω'_p but not with $\omega'_£$. The effect ω'_p causes, however, is small, and a closer inspection shows that this effect stems primarily from only one parameter-set.

So, I replicate the two types of attraction effects, but with two new observations. As predicted, Attraction Effect Chernoff appears to be weaker than Attraction Effect WARP. Second, the attraction effect I observe is considerably smaller than previously reported. For example, Herne (1999) observed an average within-subject Attraction Effect WARP of almost 24%; mine is between 4.8% and 9.7%. Yet, I still observe it despite the higher incentives, the gambles with different expected values, the more transparent incentive mechanism, and the increased concreteness of the choice situation.

5.2 There is no clear support for the weights explanation

Consider then ω''_p and $\omega''_£$. As we saw, these decoys are also asymmetrically dominated but they double the range of the weakest attribute of their associated option. The weights explanation predicts that they will cause a stronger attraction effect, while the process explanation predicts no change at all.

The results provide mixed evidence. Within-subject Attraction Effect WARP now appears in one direction only, when subjects are first exposed to $\omega''_£$, but at a higher significance level (Figure 2, top-left, third and fourth row); and so for 3 out of 4 parameter sets, compared to only one when subjects were first exposed to $\omega'_£$. Between-subject, Attraction Effect WARP is less pronounced than before (top-right, second row).

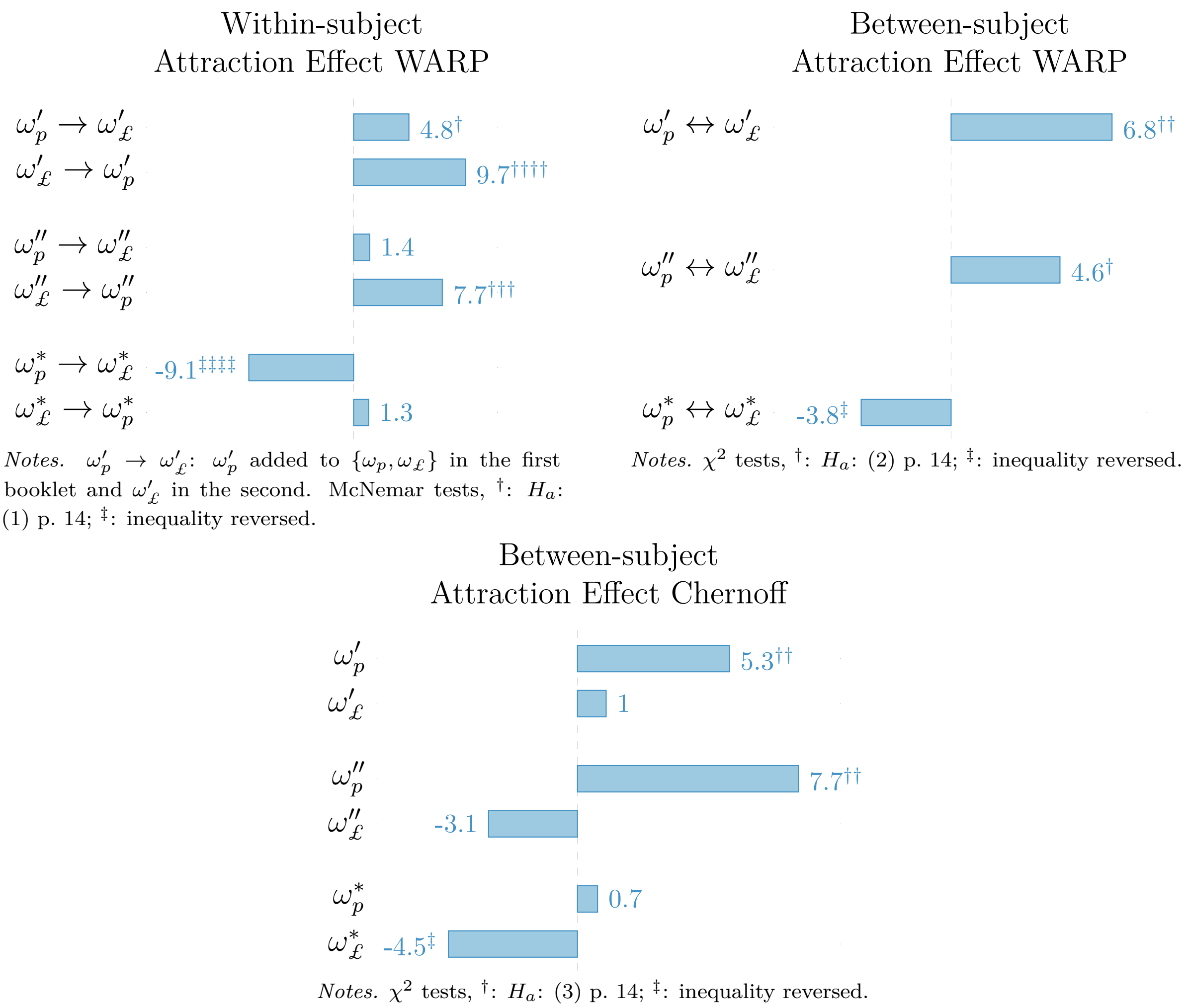

Figure 2: Attraction effects (in percent) at the aggregate level. One, two, three and four symbols indicate significance at $\alpha = 0.1$, 0.05, 0.01 and 0.001.

For Attraction Effect Chernoff (bottom, fourth row), ω''_p has more incidence than ω'_p: introducing ω''_p increases the proportion of subjects choosing ω_p by almost 8 percentage points, compared to 5 for ω'_p (bottom, third row). $\omega''_£$, just as $\omega'_£$, has no effect .

Therefore, ω''_p and $\omega''_£$ do cause an attraction effect, which reinforces the results obtained with ω'_p and $\omega'_£$; but increasing the attribute ranges does not seem to cause a stronger attraction effect, which invalidates the weights explanation.

5.3 A positive range effect operates against the attraction effect

However the real test comes from ω^*_p and $\omega^*_£$. Remember that according to the weights explanation, we should observe the same attraction effect; but according to the process explanation, the effect should vanish.

Neither is correct: Looking at within-subject Attraction Effect WARP (Figure 2, top-left, rows 5 and 6) introducing ω_p^* in the first booklet and $\omega_£^*$ in the second causes a *negative* attraction effect whereby subjects switch from $\omega_£$ to ω_p and not from ω_p to $\omega_£$. This effect is highly significant at the aggregate level, significant for 3 out of 6 parameter sets, and always in the right direction. Introducing $\omega_£^*$ first has no effect. This negative attraction effect carries over to between-subject Attraction Effect WARP (top-right, last row).

Between-subject Attraction Effect Chernoff resulting from the introduction of $\omega_£^*$ is also negative, which makes the effect clearer: introducing $\omega_£^*$ *decreases* the choice of $\omega_£$ and so increases the choice of ω_p (bottom, last row). So, instead of favouring $\omega_£$ as would predict the weights explanation, $\omega_£^*$ actually favours ω_p. Recall from Figure 1 that $\omega_£^*$ increases the range of the probability attribute. When the probability range is increased, subjects tend to chose ω_p, the superior option in terms of the probability attribute: it is a *positive range effect*. It is in line with the studies finding that people weight more an attribute when its range is greater (Fischer, 1995; Goldstein, 1990; Mellers and Cooke, 1994; von Nitzsch and Weber, 1993; Wedell, 1998; Wedell and Pettibone, 1996) and, to my knowledge, this is the fist time it appears in an incentivised, economic study.

Note that ω_p^* causes no between-subject Attraction Effect Chernoff at the aggregate level.

5.4 Decoys seldom affect $\omega_£$

In contrast to previous research, I find that not all decoys are created equal. It is clear at the bottom of Figure 2: ω_p', ω_p'' and $\omega_£^*$ trigger an effect, but $\omega_£'$, $\omega_£''$ and ω_p^* do not. ω_p', ω_p'' and $\omega_£^*$ triggering an effect means that they increase the choice of ω_p, and conversely, $\omega_£'$, $\omega_£''$ and ω_p^* triggering none means that $\omega_£$ is not responsive to decoys.

Remember that $\omega_£$ is riskier than ω_p: by choosing it, subjects faced a 45-to-70% chance of leaving the experiment empty-handed. So, a possible interpretation is that subjects might have tried to avoid $\omega_£$ instead of being attracted to it.

Results from ω^* provide some evidence supporting this interpretation. Recall that this decoy neither increases an attribute range nor is asymmetrically dominated so it should have no effect. Indeed, it has no effect between-subject. Within-subject, however, when subjects face $\{\omega_p, \omega_£\}$ in the first booklet and $\{\omega_p, \omega_£, \omega^*\}$ in the second booklet they switch more from $\omega_£$ to ω_p than they do the opposite. It is possible that introducing ω^* gave subjects a second chance to re-evaluate their decisions and move away from the riskier gamble $\omega_£$. Subjects might have imprecise preferences (Butler and Loomes, 2007) for $\omega_£$ and the chance to reconsider their choice made them realise that in fact they preferred ω_p.[12]

The lesser responsiveness of $\omega_£$ to decoys could explain the directionality of within-subject Attraction Effect WARP (Figure 2, top-left), where introducing $\omega'_£$, $\omega''_£$ or ω^*_p in the second booklet caused less or no effects. As we have just seen, these decoys have no grips on $\omega_£$ so there was no reason for subjects to change the choice they made in the first booklet when these decoys appeared in the second booklet.

These results went unnoticed in previous experiments. They illustrate the importance of combining within- and between-subject designs and studying the directionality of the effect in the same experiment. They also show that some small tweaks can make the attraction effect vanish, a sentiment shared by Frederick et al. (2014).

6 A simple model of choice in the presence of attraction and range effects

The results have revealed two effects:

- a standard attraction effect, following the introduction of ω'_p, $\omega'_£$, ω''_p and $\omega''_£$, according to which people choose more an option when it asymmetrically dominates another;
- and a positive range effect, revealed by ω^*_p and $\omega^*_£$ and triggered when asymmetric dominance is removed, which makes people weight more an attribute when its range in the menu increases.

I now want to look at the ingredients required to generate these two effects, and at what kind of model this would give rise to when incorporated in a standard model of choice.

Taking choices at face value, subjects choosing ω_p in $\{\omega_p, \omega_£\}$ and $\omega_£$ in $\{\omega_p, \omega_£, \omega'_£\}$ have revealed that ω_p in $\{\omega_p, \omega_£\}$ is not the same as ω_p in $\{\omega_p, \omega_£, \omega'_£\}$. In other words the options are menu-dependent. To make the options menu-dependent I introduce three new parameters. γ_i captures the fact that an option asymmetrically dominates another: $\gamma_i \neq 1$ when it does and $\gamma_i = 1$ when it does not. Δ_x and Δ_p capture the ranges of winning amounts and winning probabilities in the menu; they were already represented on Figure 1.

[12] I thank Robert Sugden for this observation.

Then I assume the utility function

$$\tilde{U}(x_i, p_i; \gamma_i) = \gamma_i \cdot {p_i}^{f(\Delta_p)} {x_i}^{f(\Delta_x)}.$$

To see how this utility function operates, assume for simplicity that, in the absence of decoys, a subject is initially indifferent between ω_p and $\omega_£$:

$$\omega_p \sim \omega_£ \Leftrightarrow {p_p}^{f(\Delta_p)} {x_p}^{f(\Delta_x)} = {p_£}^{f(\Delta_p)} {x_£}^{f(\Delta_x)}. \tag{4}$$

If $f'(\Delta_i) > 0$ then adding ω_p^* or $\omega_£^*$ to the menu gives rise to a positive range effect. For example $\omega_£^*$ increases Δ_p to $2 \cdot \Delta_p$, and rewriting (4) as

$$\left(\frac{p_p}{p_£}\right)^{f(\Delta_p)} = \left(\frac{x_£}{x_p}\right)^{f(\Delta_x)}$$

we see that it would tip the decision-maker into choosing ω_p. This mechanism is the flip-side of the similarity effect and is modelled similarly by Mellers and Biagini (1994). If $f'(\Delta_i) < 0$ we would have a negative range effect so $\omega_£^*$ would tip the decision-maker into choosing $\omega_£$.

Since γ_i, $f(\Delta_p)$ and $f(\Delta_x)$ are not assumed to have a particular sign, adding ω_p' and $\omega_£'$ cause two effects which are potentially conflicting. For example ω_p' increases the range of winning amounts from Δ_x to Δ_x' – this is the range effect; but it also adds an option dominated by ω_p, captured by γ_p – this is the attraction effect. If these effects are both positive ($f'(\Delta_i) > 0$ and $\gamma_i > 1$) or both negative they run against each other: A positive range effect means that moving from Δ_x to Δ_x' increases the weight on the winning amount attribute, so ω_p' favours $\omega_£$; but a positive attraction effect means that γ_p multiplies the utility of ω_p by a positive number, so ω_p' favours ω_p. Depending on which effect dominates $\tilde{U}$ can give rise to different patterns.

γ_i, Δ_x and Δ_p are black boxes, reflecting some unmodelled decision processes. They could be motivated under several accounts. One can imagine a two-stage decision process as in first-generation prospect theory (Kahneman and Tversky, 1979). In the first stage, the decision-maker scans the menu to detect asymmetric dominance and attribute ranges. If she finds an option that asymmetrically dominates another, she feels more compelled to choose it because she has more reasons to justify her choice, as in Simonson's (1989) 'choice based on reason'. If she perceives that an attribute range is larger than before, she devotes more attention to this particular attribute, à la Kőszegi and Szeidl (2013). In the second stage, these elements are combined with her standard utility function to form the distorted utility function $\tilde{U}$.

6.1 Estimation setup

To see if this model explains subjects' choices, I estimate it using a mixed logit model (Revelt and Train, 1998; Train, 2009). Assume that the probability a subject chooses ω_i from the menu is

$$\Pr(\omega_i) = \frac{\tilde{U}(\omega_i)}{\sum_i \tilde{U}(\omega_i)}, \tag{5}$$

and, for a subject n choosing alternative i in choice task t, the logit choice probability is

$$L_{nit}(\mathbb{B}_n) = \frac{\exp\Big(V(\omega_i)\Big)}{\sum_i \exp\Big(V(\omega_i)\Big)} \tag{6}$$

where

$$\begin{aligned} V(\omega_i) = \beta_{n,\mathrm{d}} \mathbb{1}_{i,\mathrm{decoy}} &+ \Big(\beta_{n,p}^{\Delta_p} + \beta_{n,p}^{\Delta'_p} \mathbb{1}_{\Delta'_p} + \beta_{n,p}^{2\Delta_p} \mathbb{1}_{2\Delta_p}\Big) \ln p_i \\ &+ \Big(\beta_{n,x}^{\Delta_x} + \beta_{n,x}^{\Delta'_x} \mathbb{1}_{\Delta'_x} + \beta_{n,x}^{2\Delta_x} \mathbb{1}_{2\Delta_x}\Big) \ln x_i \end{aligned}$$

with $\mathbb{1}$ an indicator function equal to 1 if the condition specified in its subscript is verified, and 0 otherwise. So, $\mathbb{1}_{i,\mathrm{decoy}} = 1$ if option i asymmetrically dominates a decoy – ω'_i or ω''_i – and $\mathbb{1}_{i,\mathrm{decoy}} = 0$ if it does not, either because there are no decoys or because the decoy is symmetrically dominated, as it is the case with ω^*_i and ω^*. Similarly, $\mathbb{1}_{\Delta'_p} = 1$ in case of small extension of the probability range with ω'_2; and $\mathbb{1}_{2\Delta_p} = 1$ if the probability range is doubled with ω''_2 or ω^*_2; and the same for $\mathbb{1}_{\Delta'_x}$ and $\mathbb{1}_{2\Delta_x}$ for the extension of the range of winning amounts.

(6) is a rearrangement of (5) if we set

$$\begin{aligned} \ln \gamma_i &= \beta_{n,\mathrm{d}}, \\ f(\Delta_p) &= \beta_{n,p}^{\Delta_p} + \beta_{n,p}^{\Delta'_p} \mathbb{1}_{\Delta'_p} + \beta_{n,p}^{2\Delta_p} \mathbb{1}_{2\Delta_p}, \\ f(\Delta_x) &= \beta_{n,x}^{\Delta_x} + \beta_{n,x}^{\Delta'_x} \mathbb{1}_{\Delta'_x} + \beta_{n,x}^{2\Delta_x} \mathbb{1}_{2\Delta_x}, \end{aligned}$$

so $\beta_{n,\mathrm{d}}$ captures the effect of introducing an asymmetrically dominated decoy; $\beta_{n,p}^{\Delta_p}$ and $\beta_{n,x}^{\Delta_x}$ capture the baseline attitude toward probabilities and winning amounts; and $\beta_{n,p}^{\Delta'_p}$, $\beta_{n,p}^{2\Delta_p}$, $\beta_{n,x}^{\Delta'_x}$ and $\beta_{n,x}^{2\Delta_x}$ capture the effect of increasing the range of probabilities or winning amounts. To see this, denote by $\tilde{\tilde{U}}$ the natural logarithm transformation of $\tilde{U}$, so

$\tilde{\tilde{U}}(\omega_i) = \ln \gamma_i + \Delta_p \ln p_i + \Delta_x \ln x_i$ and rewrite (5) as

$$\Pr(\omega_i) = \frac{\exp\left(\tilde{\tilde{U}}(\omega_i)\right)}{\sum_i \exp\left(\tilde{\tilde{U}}(\omega_i)\right)}.$$

We can expect $\beta_{n,\mathrm{d}} > 0$, a positive attraction effect stemming from the introduction of an asymmetrically dominated decoy, but nothing prevents it from being negative. We can also expect that $\beta_{n,p}^{\Delta'_p},\ \beta_{n,p}^{2\Delta_p},\ \beta_{n,x}^{\Delta'_x},\ \beta_{n,x}^{2\Delta_x} > 0$, which would correspond to a positive range effect, but they might be negative, corresponding to a negative range effect.

The mixed logit model accounts for preference heterogeneity by estimating both the mean and the standard deviation of the parameters. As a consequence it also accounts for correlation across choice tasks for a given subject. It also controls from order effect since each choice task serves as its own control, which it inherits from the conditional logit model. For these reasons mixed logit models are increasingly used to analyse repeated choice data (see Stewart et al., 2014, for a recent example).

6.2 Estimation results

Table 3 presents the estimation results.[13] All coefficients are assumed to be normally distributed; the top part of the Table contains the estimates of the mean and the bottom those of the standard deviation. I estimated three models, all on the complete dataset: a baseline model (1) without attraction and range effects; a model (2) with attraction effect only; and a full model (3) with attraction and range effects. A likelihood-ratio test shows that adding the attraction-effect parameter $\mathbb{1}_{i,\mathrm{decoy}}$ to the baseline model results in a statistically significant increase in model fit ($\chi^2(2) = 17.29$, $p < 0.01$). Adding the range parameters $\mathbb{1}_{\Delta'_p}$, $\mathbb{1}_{2\Delta_p}$, $\mathbb{1}_{\Delta'_x}$ and $\mathbb{1}_{2\Delta_x}$ on top also results in a statistically significant increase in model fit ($\chi^2(8) = 21.51$, $p < 0.01$).

The estimation results generally confirm the results from the previous Section. Looking at the means of model (3) (Table 3, top-right), we see that $\beta_{n,\mathrm{d}} = 0.541$ so $\gamma_i \simeq 1.72$: adding an asymmetrically dominated decoy boosts the utility of the dominating gamble. This confirms the positive attraction effect stemming from the process explanation. Further, the coefficients of $\ln(p) \times \mathbb{1}_{\Delta'_p}$ and $\ln(p) \times \mathbb{1}_{2\Delta_p}$ are positive and significant, which means that, by widening the probability range, $\omega'_£$, $\omega''_£$ and $\omega^*_£$ increase the choice of ω_p. This confirms the positive range effect. The regression then confirms the idea expressed earlier that $\omega'_£$ and $\omega''_£$ cause two conflicting effects: they favour $\omega_£$ due to the

[13] The Stata command `mixlogit` from Hole (2007) was used.

Table 3: Results from the mixed logit model.

	Estimates		
	(1) *Coef. (SE)*	(2) *Coef. (SE)*	(3) *Coef. (SE)*
Mean			
$\ln(p)$	18.801***	18.414***	18.055***
	(0.837)	(0.842)	(0.903)
$\ln(x)$	11.176***	10.923***	10.767***
	(0.582)	(0.593)	(0.613)
$\mathbb{1}_{i,\text{decoy}}$		0.286***	0.541***
		(0.069)	(0.115)
$\ln(p) \times \mathbb{1}_{\Delta'_p}$			1.606**
			(0.592)
$\ln(p) \times \mathbb{1}_{2\Delta_p}$			0.998**
			(0.318)
$\ln(x) \times \mathbb{1}_{\Delta'_x}$			0.043
			(0.338)
$\ln(x) \times \mathbb{1}_{2\Delta_x}$			0.187
			(0.199)
Standard deviation			
$\ln(p)$	3.281***	2.832**	3.495***
	(0.593)	(0.945)	(0.591)
$\ln(x)$	4.407***	4.478***	4.471***
	(0.305)	(0.344)	(0.305)
$\mathbb{1}_{i,\text{decoy}}$		0.003	0.050
		(0.146)	(0.146)
$\ln(p) \times \mathbb{1}_{\Delta'_p}$			3.077***
			(0.785)
$\ln(p) \times \mathbb{1}_{2\Delta_p}$			0.378
			(0.689)
$\ln(x) \times \mathbb{1}_{\Delta'_x}$			0.356
			(1.424)
$\ln(x) \times \mathbb{1}_{2\Delta_x}$			0.067
			(1.106)
Observations	15934	15934	15934
Log-likelihood	−2669.721	−2661.076	−2650.323
Wald χ^2	2694.916	2700.329	2705.354
Prob > χ^2	0.000	0.000	0.000

Notes. $\ln(p)$ and $\ln(x)$ capture the baseline attitude toward probabilities and winning amounts when the attribute ranges are Δ_p and Δ_x. $\ln(p) \times \mathbb{1}_{\Delta'_p}$ and $\ln(p) \times \mathbb{1}_{2\Delta_p}$ capture the effect of increasing the range of probabilities to Δ'_p and $2\Delta_p$; and $\ln(x) \times \mathbb{1}_{\Delta'_x}$ and $\ln(x) \times \mathbb{1}_{2\Delta_x}$ of increasing the range of winning amounts to Δ'_x and $2\Delta_x$. $\mathbb{1}_{i,\text{decoy}}$ captures the effect of introducing an asymmetrically dominated decoy.
All coefficients are assumed to be normally distributed. The top and bottom part of the table report the mean and the standard deviation of the distributions.
Number of Halton draws used for simulation: 1000
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

positive attraction effect, but they also favour ω_p due to the positive range effect. When $\omega^*_£$ removes the asymmetric dominance, the positive range effect is left to operate alone, which favours ω_p only.

We also see that the coefficient for $\ln(p) \times \mathbb{1}_{\Delta'_p}$ is greater than the one for $\ln(p) \times \mathbb{1}_{2\Delta_p}$: moderately increasing the probability range (Δ'_p) causes a greater positive range effect than doubling it ($2\Delta_p$). The positive range effect might not be a linear function of the range extension, but rather decrease in intensity as the range increases. Huber et al. (2014) point out that for context effects to work, the decoy should not be undesirable and 'too far' from its target. $\omega'_£$ and $\omega^*_£$ are certainly undesirable: as we saw in Figure 1 and Table 1 they offer the lowest probability of winning a not-so-great amount of money. It is possible that the positive range effect decreases in intensity because some subjects simply stopped considering the decoys when they were too far from $\omega_£$.[14]

Finally, the coefficients for $\ln(x) \times \mathbb{1}_{\Delta'_x}$ and $\ln(x) \times \mathbb{1}_{2\Delta_x}$ are not statistically significantly different from 0, so increasing the range of winning amounts do not trigger any range effect. Thus, ω'_p and ω''_p only cause an attraction effect, which favours ω_p, but not a positive range effect, which would have favoured $\omega_£$. This finding corroborates the results from Section 5.4, in which we saw that $\omega_£$ is less responsive to decoys than ω_p.

6.3 Attraction effect versus range effect

Now have a look at the standard deviation estimates at the bottom of Table 3. These estimates highlight the necessity of the mixed logit model: preferences are heterogeneous and not all subjects place the same weight on winning probabilities and winning amounts.

More importantly, subjects also differ in how they respond to the small probability-range extension brought by $\omega'_£$: the estimate of the standard deviation of the coefficient for $\ln(p) \times \mathbb{1}_{\Delta'_p}$ is significant and equal to 3.077. Since the estimate of the mean of the same coefficient is equal to 1.606, some subjects have a negative coefficient; in fact, about 30% do so.[15] As a consequence, while most subjects exhibit a positive range effect working against the attraction effect, 30% exhibit a negative range effect, as predicted by the weights explanation. For these 30%, extending the range of probabilities work *in favour* of the attraction effect. If we restrict the analysis to these subjects, we should observe even more attraction effect because the two effects reinforce each other. Conversely, if we restrict to subjects who exhibit a strong positive range effect, we should observe less,

[14] I am grateful to Alexia Gaudeul for this remark.

[15] Since the parameters are normally distributed, and denoting by Φ the cumulative standard normal distribution, the percentage of subjects with a parameter below 0 is $100 \cdot \Phi\left(-1.606/3.077\right)$.

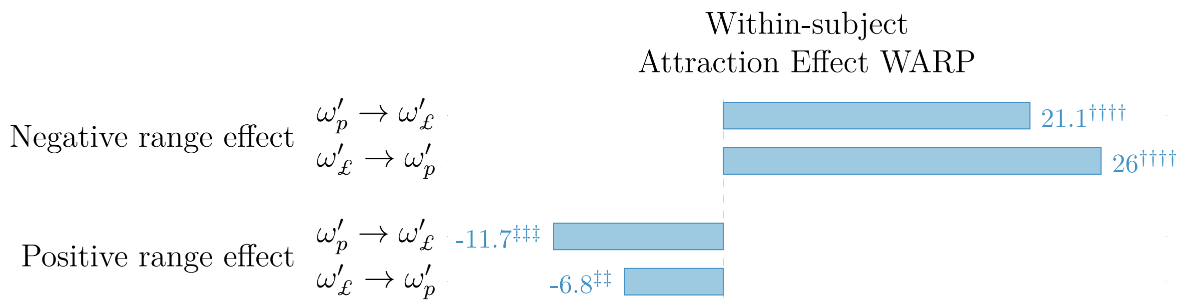

Figure 3: Attraction effect (in percent) at the aggregate level, as a function of the strength of the range effect.

Notes. Negative and positive range effects are defined as subjects whose range effect ($\ln(p) \times \mathbb{1}_{\Delta'_p}$) is smaller or greater than the median. One, two, three and four symbols indicate significance at $\alpha = 0.1$, 0.05, 0.01 and 0.001. $\omega'_p \to \omega'_£$: ω'_p added in the first booklet and $\omega'_£$ in the second. McNemar tests, †: H_a: (1) p.14; ‡: inequality reversed.

no, or even a negative attraction effect.

To verify this prediction, I use the procedure depicted by Train and Revelt (1999) to assign each subject her coefficient for $\ln(p) \times \mathbb{1}_{\Delta'_p}$.[16] Once each subject has been assigned her coefficient, I split the subjects into two groups depending on whether their parameter fall above or below the median of the parameter. For subjects below the median the extension of the probability range brought by $\omega'_£$ causes a small positive or a negative range effect, which is likely to reinforce the attraction effect; for those above the median the extension causes a strong positive range effect which could negate or even reverse the attraction effect. Then, I recompute within-subject Attraction Effect WARP, as in equation (1), and replot Figure 1 top-left, separately for each group.

Figure 3 presents the results of this analysis. As predicted, subjects with a small positive or a negative range effect exhibit a stronger attraction effect. It is as high as 26%, in line with the results from Herne (1999). But subjects with a strong positive range effect exhibit no attraction effect. They even exhibit the opposite, a negative attraction effect, similar to what happens with $\omega^*_£$.

So, asymmetrically dominated decoys do not affect everyone in the same way. They can tip choice into one direction or the other, depending on the sign and the strength of the range effect. While on average the attraction effect is as predicted, for some people the positive range effect takes over. This illustrates the importance of using a model able to capture preference heterogeneity, such as the mixed logit model, to analyse the results from such experiments.

[16]The Stata post-estimation command `mixlbeta`, also from Hole (2007), was used.

7 Conclusion

The experiment I have presented replicates the attraction effect, by which an asymmetrically dominated decoy favours the dominating option. Compared to the previous literature this experiment reports a smaller effect, impacting only a minority of subjects; however it is still there despite the higher incentives, gambles differing in expected values and more transparent procedures. The results also show the existence of a range effect that supports focusing and salience theories.

All in all the attraction effect is a challenge for standard theories of choice. It is only one of several context effects, alongside the compromise effect (Simonson, 1989) and the similarity effect (Tversky, 1972). Failure of procedure invariance, such as the well-known preference reversal phenomenon between choice and valuation (Cubitt et al., 2004; Plott and Grether, 1979; Tversky et al., 1990), also attacks the concept of preference. One can wonder how far tweaking the theories to encompass all possible anomalies will carry us. There have been calls to abandon preferences and embrace a new paradigm based on information processing (Oppenheimer and Kelso, 2015); a call followed for some time by behavioural sciences outside economics which gave rise to, for example, decision-field theory (Roe et al., 2001), the leaky competing accumulator model (Usher and McClelland, 2004) and decision-by-sampling (Stewart et al., 2014). While the attraction effect does exist, most subjects were consistent in the experiment reported in this paper, which may well justify the reluctance of economists to abandon preferences altogether.

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Appendices

Appendix A Details of the experiment

This Appendix provides additional details on the experiment. Appendix A.1 gives a sample of a choice task found in a decision booklet. Appendix A.2 describes how the experiment was conducted and how the PRINCE mechanism was implemented. Appendix A.3 reproduces the instructions.

A.1 Sample choice task

In one of the envelopes, the options are:

	1 – 80	81 – 100
P	£7	£0

	1 – 55	56 – 100
Q	£12.5	£0

If these options are the ones in my envelope, give me option: (write P or Q in the box)

- writing **P** means that I will receive £7 if the dice throw yields a number from 1 to 80, and £0 otherwise;
- writing **Q** means that I will receive £12.5 if the dice throw yields a number from 1 to 55, and £0 otherwise.

A.2 Procedure

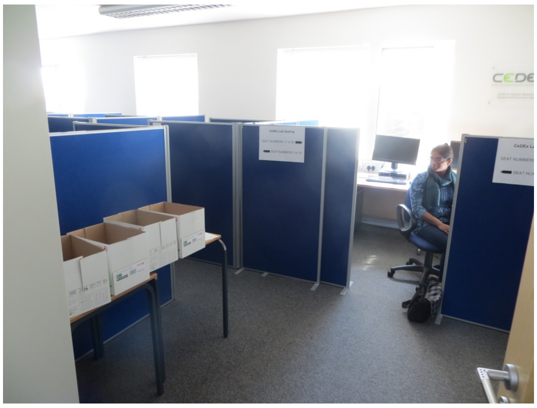
Subjects waited outside the laboratory in line. An experimenter controlled their student card against the list generated by ORSEE and let them enter. Once inside the laboratory (Picture 4a) they were greeted by a second experimenter who asked them to draw a number from a pouch. This number determined their seat number as well as their group, as defined in Table 2 of the main text. They were then directed to take an envelope from the box corresponding to their group (Picture 4b). In each box were approximately 190 envelopes (Picture 4c). Inside each envelope was a piece of paper describing one of the 28 choice tasks that a member of the group assigned to this box could encounter in the experiment. Subjects were instructed to take this envelope with them but to not open it – all subjects obeyed this instruction. The draw of the envelope was without replacement.

Subjects then went to their assigned desk. There they found the instructions, a pen and two 10-sided dice (Picture 4d). Once everyone was seated the experimenter started reading the instructions, which are found in Appendix A.3. The experimenters also controlled subjects' answers to the control questions. Then, the experimenters distributed the first decision booklet and the subjects started completing the 14 tasks contained inside. Depending on their seat number and so their group, subjects received different booklets. The booklets differed in the decoys seen, again as described in Table 2 of the main text. Appendix A.1 provides a sample of a choice task found in the booklets.

In the instructions subjects were instructed to raise their hand when they would finish the first booklet. As soon as a subject did the experimenters went to see her, collected the first booklet and gave her the second booklet containing 14 additional choice tasks. On average subjects took 15 minutes to complete each booklet.

Subjects were further instructed to raise their hand when they would finish the second booklet. Once everyone had finished the experimenters started the payment phase. When an experimenter came to a subject the experimenter gave her her first booklet. Then, the experimenter asked the subject to open the envelope and they flipped through the two booklets to find the choice task described on the piece of paper. Together they looked at the gamble the subject chose in this particular choice task and the experimenter read out loud the text at the bottom of the choice task (Appendix A.1) describing what would happen depending on the result of the dice. The experimenter asked the subject to draw her dice and, depending on the result, the subject won or lost. In any case the subject also received a show-up fee, of which they were not aware before this moment. The experimenter wrote the final payoff of the subject on a piece of paper, which the subject took to the centre of the room where a third experimenter collected it and paid the subject accordingly. Finally the subject exited the room

In total the experiment took about 1 hour.



(a) Entering the laboratory.

(b) Boxes containing the envelopes.

(c) Inside a box.

(d) A subject's desk.

Figure 4: Pictures of the experiment.

A.3 Instructions

The next pages reproduces the instructions as they were seen by the subjects – they are here reproduced two-pages-on-one to save space.

Instructions

Welcome to the experiment. Please switch off your electronic devices and remain silent. If you have a question at any time, raise your hand and an experimenter will come to your desk to answer it.

* * *

In this experiment, you will face options that give you chances to win amounts of money. An option is for example a 20%-chance of winning £35.

To represent the chances of winning, we will refer to the dice placed on your desk, which you are welcome to examine as much as you want throughout the experiment. One die is used for the tens and the other for the units. Throwing the dice together and adding the results yields a number from 1 to 100. For example, the throw below is 31:

The next one is 8:

100 is obtained by getting zeros on both dice. Each ten and each unit is equally likely, so *each number from 1 to 100 is also equally likely*.

In terms of the dice, the 20%-chance of winning £35 is equivalent to £35 for numbers from 1 to 20, and £0 for numbers from 21 to 100. We will represent it as follows:

1 – 20	21 – 100
£35	£0

This means that, if the dice throw yields a number from 1 to 20, you will receive £35. If it yields a number from 21 to 100, you will receive £0.

* * *

All tasks in this experiment will ask you to select one from a set of two or three such options. The options in these tasks are always gambles which will feature different chances of winning various amounts of money. You will record your selected option in each of these tasks in decision booklets, which we will distribute soon. There will be a different task of this form on each page.

You will play one of the gambles that you select for real at the end of the experiment, meaning that you might win some money in this real task. The task that is real for you has already been selected in the following way: When you entered the room, you picked one from a set of envelopes. Each envelope contains a piece of paper describing one of the tasks that you will face in your booklet. Any one of the tasks that you face could be for real, but you will not know which one is for real until the end of the experiment.

At the end of the experiment, an experimenter will come to your desk and open your envelope. The piece of paper in the envelope will show the task that will be real for you. The experimenter will then look in your decision booklet to see which option you picked in this task. That option will be a gamble which will specify an amount of money that you can win depending on the throw of the dice. You will then roll the dice to see whether you earn money from the real task or not. If you win, you will be paid in cash the amount specified in your chosen option.

So, as you respond to the tasks remember that for each task, the option that you pick could turn out to be the one that you play for real at the end of the experiment. Because of this, we suggest that you treat each task as if it is for real and as if it is the only task you face since at the end of the experiment you will only face one task for real (i.e. the one contained in the envelope you now have).

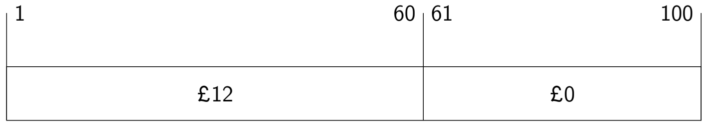
Let us illustrate this with an example.

Imagine that one of the pages of the decision booklet is as follows: (The presentation will be the same, but the options will be different.)

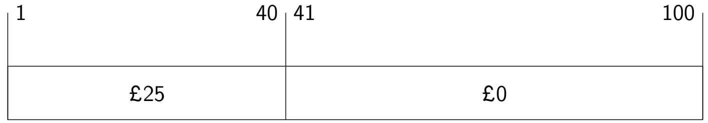
Page A

In one of the envelopes, the options are:

P



Q



If these options are the ones in my envelope, give me option: (write P or Q in the box)

P

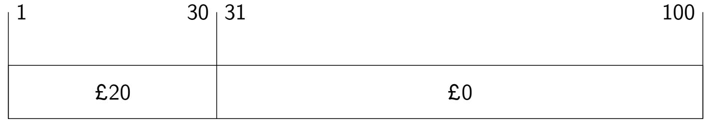
- writing **P** means that I will receive £12 if the dice throw yields a number from 1 to 60, and £0 otherwise;
- writing **Q** means that I will receive £25 if the dice throw yields a number from 1 to 40, and £0 otherwise.

This example assumes that you chose option P.
Then, imagine that another page of the decision booklet is:

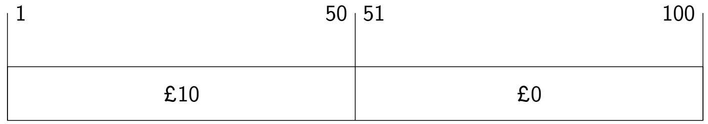
Page B

In one of the envelopes, the options are:

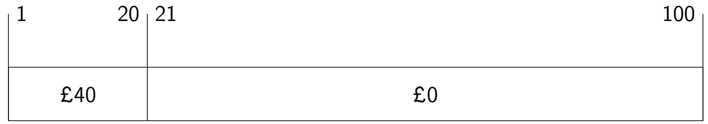
P



Q



R



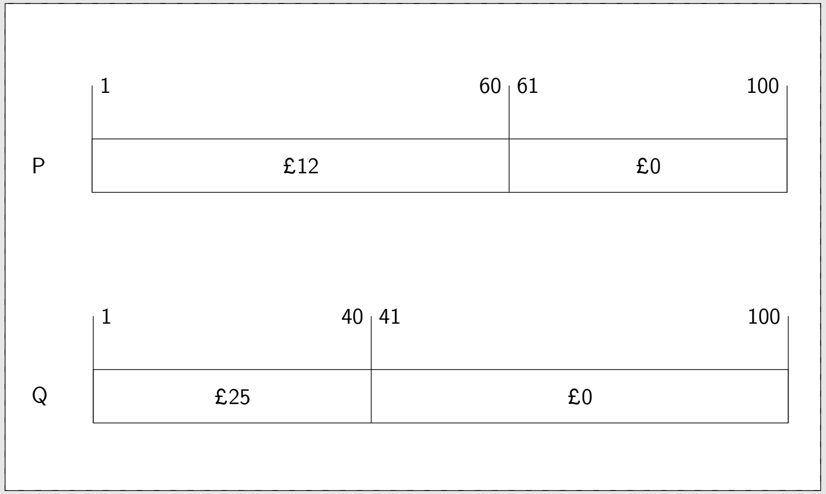
If these options are the ones in my envelope, give me option: (write P, Q or R in the box)

R

- writing **P** means that I will receive £20 if the dice throw yields a number from 1 to 30, and £0 otherwise;
- writing **Q** means that I will receive £10 if the dice throw yields a number from 1 to 50, and £0 otherwise;
- writing **R** means that I will receive £40 if the dice throw yields a number from 1 to 20, and £0 otherwise.

Here, we assume that you chose option R.

At the end of the experiment, the experimenter comes to your desk and opens your envelope. Suppose that your envelope contains:



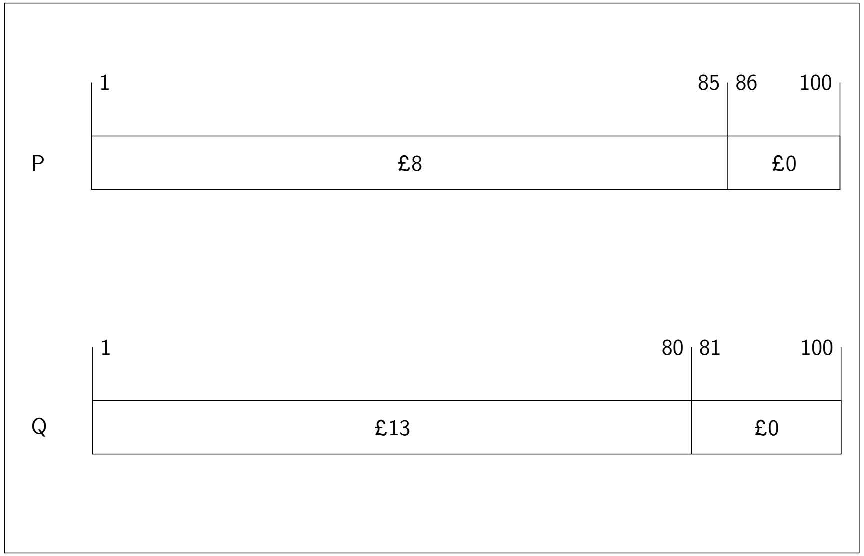
The experimenter will look for these options in your decision booklet. They were in Page A above and we assumed that you chose option P. The experimenter will then throw the dice. In accordance with what is written in the decision booklet, you would get £12 if the throw yields a number from 1 to 60, and £0 if it yields a number from 61 to 100.

Questions

We want to make sure you understand the procedure fully, so we have designed two questions to test your understanding. These questions have no bearing on the rest of the experiment. Please answer them and raise your hand when you have finished; an experimenter will come to verify your responses.

Question 1

Imagine that the options in your envelope are:



These two options are the ones on the following page of the decision booklet:

In one of the envelopes, the options are:

	1 – 85	86 – 100
P	£8	£0

	1 – 80	81 – 100
Q	£13	£0

If these options are the ones in my envelope, give me option: (write P or Q in the box)

$\boxed{}$

- writing **P** means that I will receive £8 if the dice throw yields a number from 1 to 85, and £0 otherwise;
- writing **Q** means that I will receive £13 if the dice throw yields a number from 1 to 80, and £0 otherwise.

What happens if:

- you write **P** and the dice throw yields **81**? ....
- you write **P** and the dice throw yields **91**? ....
- you write **Q** and the dice throw yields **81**? ....
- you write **Q** and the dice throw yields **10**? ....

Question 2

Suppose that you encounter the next two pages in your decision booklet and make the following choices:

Page A

In one of the envelopes, the options are:

	1–70	71–100
P	£14	£0

	1–20	21–100
Q	£35	£0

If these options are the ones in my envelope, give me option: (write P or Q in the box)

Q

- writing **P** means that I will receive £14 if the dice throw yields a number from 1 to 70, and £0 otherwise;
- writing **Q** means that I will receive £35 if the dice throw yields a number from 1 to 20, and £0 otherwise.

Page B

In one of the envelopes, the options are:

	1–20	21–100
P	£50	£0

	1–50	51–100
Q	£12	£0

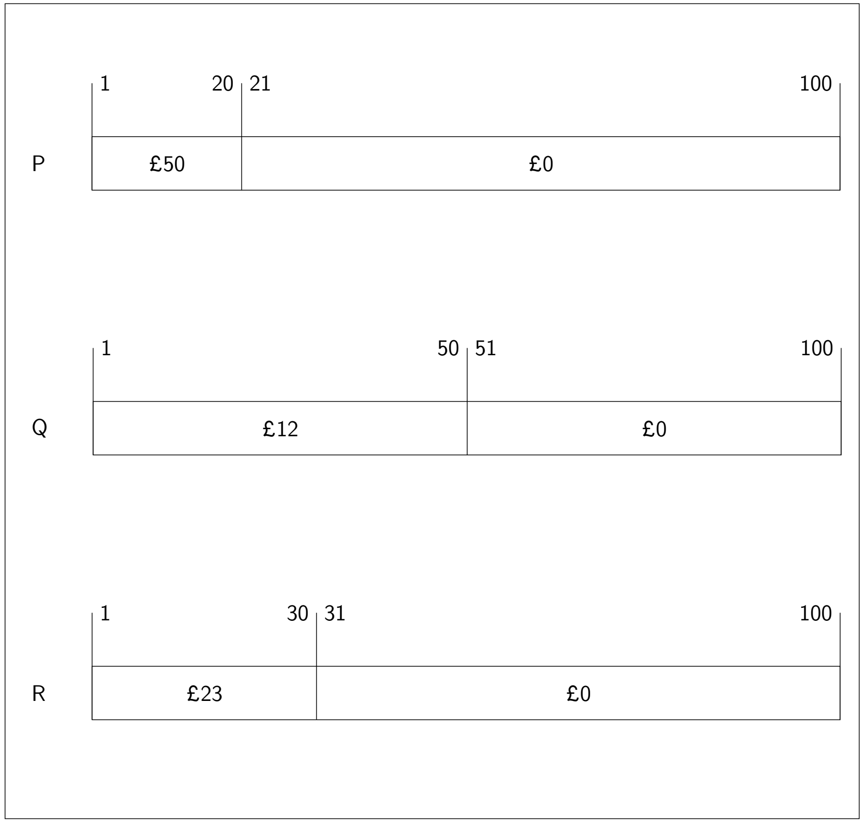
	1–30	31–100
R	£23	£0

If these options are the ones in my envelope, give me option: (write P, Q or R in the box)

R

- writing **P** means that I will receive £50 if the dice throw yields a number from 1 to 20, and £0 otherwise;
- writing **Q** means that I will receive £12 if the dice throw yields a number from 1 to 50, and £0 otherwise;
- writing **R** means that I will receive £23 if the dice throw yields a number from 1 to 30, and £0 otherwise.

If the options in your envelope are:



Which option is going to be played for real? ....

If the dice throw yields 24, what happens? ....
....

We are now ready to distribute the first decision booklet. You can start completing it as soon as you get it. When you have finished, raise your hand; we will collect your booklet and give you a second one for you to complete.

Appendix B Result tables

This Appendix provides disaggregated and detailed results corresponding to all aggregated results encountered in the main text. The Tables are as follows:

- Table 4 reports within-subject results corresponding Figure 2 top-left in the main text;
- Table 5 reports between-subject results corresponding Figure 2 top-right and bottom in the main text;
- Table 6 reports within-subject results with ω^*;
- Table 7 reports between-subject results with ω^*;
- Table 8 reports within-subjects results with ω'_p and $\omega'_£$ as a function of the range effect, corresponding to Figure 3 in the main text.

The different Attraction Effects are computed as follows:

- *Within-subject Attraction Effect WARP*: from Table 4 and 8,
  - when the decoy of ω_p is seen first (e.g. $\omega'_p \rightarrow \omega'_£$), it is the percentage of subjects who switch from ω_p to $\omega_£$ (column ω_p then $\omega_£$) minus the percentage of subjects who switch from $\omega_£$ from ω_p (column $\omega_£$ then ω_p);
  - when the decoy of $\omega_£$ is seen first (e.g. $\omega'_£ \rightarrow \omega'_p$), it is the percentage of subjects who switch from $\omega_£$ to ω_p (column $\omega_£$ then ω_p) minus the percentage of subjects who switch from ω_p from $\omega_£$ (column ω_p then $\omega_£$).

  Table 6 uses a similar definition but the test is two-sided since there is no expected effect.

- *Between-subject Attraction Effect WARP*: from Table 5,
  - it is the percentage of subjects who choose ω_p when the decoy is related to ω_p (column Decoy under ω_p) minus the percentage of subjects who choose ω_p when the decoy is related to $\omega_£$. *Note that this last percentage is not displayed directly on the Table*: it is roughly 100 minus the percentage of subjects who choose $\omega_£$ when the decoy is related to $\omega_£$ (column Decoy under $\omega_£$) but not exactly since some subjects chose the Decoy and these subjects are not displayed on the Table. However since the Decoy was very rarely chosen (less than 10 times across the whole experiment) this has a small impact on the numbers. The Figures in the main text report exact percentages, that is they take care of these few subjects who chose the Decoy.
  - It is also the percentage of subjects who choose $\omega_£$ when the decoy is related to $\omega_£$ (column Decoy under $\omega_£$) minus the percentage of subjects who choose $\omega_£$ when the decoy is related to ω_p. The same remark applies.

  The result of the χ^2 test is reported in the rightmost column.

- *Between-subject Attraction Effect Chernoff*: from Table 5,
  - when the decoy is related to ω_p (e.g. ω'_p), it is the percentage of subjects who choose ω_p when there is a decoy (column Decoy under ω_p) minus the percentage of subjects who choose ω_p when there is no decoy (column No decoy under ω_p);
  - when the decoy is related to $\omega_£$ (e.g. $\omega'_£$), it is the percentage of subjects who choose $\omega_£$ when there is a decoy (column Decoy under $\omega_£$) minus the percentage of subjects who choose $\omega_£$ when there is no decoy (column No decoy under $\omega_£$).

  Table 7 uses a similar definition but, again, the test is two-sided since there is no expected effect.

Table 4: Percentage (n) of choice patterns by class of decoy and presentation order (within-subject).

Set		ω_p then ω_p	$\omega_\pounds$ then $\omega_\pounds$	ω_p then $\omega_\pounds$	$\omega_\pounds$ then ω_p	χ^2		ω_p then ω_p	$\omega_\pounds$ then $\omega_\pounds$	ω_p then $\omega_\pounds$	$\omega_\pounds$ then ω_p	χ^2
a	$\omega'_p \to \omega'_\pounds$	43.1 (22)	33.3 (17)	11.8 (6)	9.8 (5)	0.09	$\omega'_\pounds \to \omega'_p$	36.5 (19)	40.4 (21)	7.7 (4)	15.4 (8)	1.33
f		32.7 (17)	46.1 (24)	11.5 (6)	3.9 (2)	2.00†		41.2 (21)	29.4 (15)	2.0 (1)	25.5 (13)	10.29††††
k		61.1 (33)	11.1 (6)	20.4 (11)	7.4 (4)	3.27††		72.0 (36)	12.0 (6)	6.0 (3)	10.0 (5)	0.50
n		34.0 (17)	46.0 (23)	8.0 (4)	12.0 (6)	0.40		42.6 (23)	46.3 (25)	3.7 (2)	7.4 (4)	0.67
Aggregate		43.0 (89)	33.8 (70)	13.0 (27)	8.2 (17)	2.27†		47.8 (99)	32.4 (67)	4.8 (10)	14.5 (30)	10.00††††
e	$\omega''_p \to \omega''_\pounds$	51.9 (28)	25.9 (14)	13.0 (7)	9.3 (5)	0.33	$\omega''_\pounds \to \omega''_p$	56.0 (28)	22.0 (11)	6.0 (3)	16.0 (8)	2.27†
i		42.3 (22)	38.5 (20)	13.5 (7)	5.8 (3)	1.60		60.8 (31)	11.8 (6)	7.8 (4)	19.6 (10)	2.57†
j		62.8 (32)	17.7 (9)	11.8 (6)	7.8 (4)	0.40		53.9 (28)	34.6 (18)	1.9 (1)	9.6 (5)	2.67†
m		48.0 (24)	30.0 (15)	6.0 (3)	16.0 (8)	2.27‡		46.3 (25)	25.9 (14)	13.0 (7)	14.8 (8)	0.07
Aggregate		51.2 (106)	28.0 (58)	11.1 (23)	9.7 (20)	0.21		54.1 (112)	23.7 (49)	7.3 (15)	15.0 (31)	5.57†††
b	$\omega^*_p \to \omega^*_\pounds$	31.4 (16)	47.1 (24)	7.8 (4)	13.7 (7)	0.82	$\omega^*_\pounds \to \omega^*_p$	43.1 (22)	33.3 (17)	7.8 (4)	15.7 (8)	1.33
c		36.0 (18)	52.0 (26)	2.0 (1)	10.0 (5)	2.67‡		37.0 (20)	44.4 (24)	9.3 (5)	9.3 (5)	0.00
d		60.8 (31)	27.5 (14)	3.9 (2)	7.8 (4)	0.67		44.2 (23)	40.4 (21)	5.8 (3)	9.6 (5)	0.50
g		49.0 (25)	25.5 (13)	2.0 (1)	23.5 (12)	9.31‡‡‡		40.4 (21)	42.3 (22)	3.9 (2)	13.5 (7)	2.78††
h		29.6 (16)	50.0 (27)	5.6 (3)	14.8 (8)	2.27‡		10.0 (5)	54.0 (27)	22.0 (11)	14.0 (7)	0.89
l		38.0 (19)	44.0 (22)	6.0 (3)	12.0 (6)	1.00		44.4 (24)	35.2 (19)	13.0 (7)	7.4 (4)	0.82
Aggregate		40.7 (125)	41.0 (126)	4.6 (14)	13.7 (42)	14.00‡‡‡‡		36.7 (115)	41.5 (130)	10.2 (32)	11.5 (36)	0.24

Notes. Subjects choosing the decoy not shown.
ω_p then ω_p: subject chooses ω_p in the first booklet and ω_p in the second booklet.
$\omega'_p \to \omega'_\pounds$: ω'_p added to $\{\omega_p, \omega_\pounds\}$ in the first booklet and $\omega'_\pounds$ in the second.
McNemar tests. One, two, three and four symbols indicate significance at $\alpha = 0.1$, 0.05, 0.01 and 0.001.
†: H_a: (1) p.14; ‡: inequality reversed.

Table 5: Percentage (n) choosing a gamble type as a function of the decoy (between-subject).

Set		ω_p				$\omega_{£}$			χ^2
		No decoy	Decoy	χ^2		No decoy	Decoy	χ^2	
a		51.0 (53)	53.4 (55)	0.18		49.0 (51)	50.5 (52)	0.04	0.40
f		36.5 (38)	56.3 (58)	$8.98^{\dagger\dagger\dagger}$		63.5 (66)	56.3 (58)	0.78	4.46^{**}
k	ω'_p	79.6 (82)	81.7 (85)	0.15	$\omega'_{£}$	20.4 (21)	26.9 (28)	1.22	2.23^{*}
n		49.5 (51)	46.2 (48)	0.23		50.5 (52)	53.9 (56)	0.23	0.00
Aggregate		54.1 (224)	59.4 (246)	$2.78^{\dagger\dagger}$		45.9 (190)	46.9 (194)	0.12	4.03^{**}
e		64.1 (66)	68.3 (71)	0.41		35.9 (37)	38.5 (40)	0.14	1.03
i		54.8 (57)	68.0 (70)	$3.78^{\dagger\dagger}$		45.2 (47)	41.8 (43)	0.25	2.09^{*}
j	ω''_p	54.8 (57)	68.9 (71)	$4.37^{\dagger\dagger}$	$\omega''_{£}$	45.2 (47)	36.9 (38)	1.47	0.78
m		58.3 (60)	57.7 (60)	0.01		41.8 (43)	38.5 (40)	0.23	0.32
Aggregate		58.0 (240)	65.7 (272)	$5.24^{\dagger\dagger}$		42.0 (174)	38.9 (161)	0.85	1.88^{*}
b		41.4 (43)	49.0 (50)	1.22		58.7 (61)	52.4 (54)	0.81	0.04
c		52.4 (54)	42.3 (44)	$2.13^{\ddagger}$		47.6 (49)	53.9 (56)	0.81	0.31
d		43.7 (45)	59.2 (61)	$4.98^{\dagger\dagger}$		56.3 (58)	40.8 (42)	$4.98^{\ddagger\ddagger}$	0.00
g	ω^*_p	47.1 (49)	52.4 (54)	0.58	$\omega^*_{£}$	52.9 (55)	41.8 (43)	$2.57^{\ddagger}$	0.71
h		37.9 (39)	29.8 (31)	1.50		62.1 (64)	61.5 (64)	0.01	1.73^{*}
l		54.4 (56)	48.1 (50)	0.82		45.6 (47)	46.2 (48)	0.01	0.69
Aggregate		46.1 (286)	46.8 (290)	0.05		53.9 (334)	49.4 (307)	$2.44^{\ddagger}$	$1.78^{\star}$

Notes. χ^2 tests. One, two and three symbols indicate significance at $\alpha = 0.1$, 0.05 and 0.01.
†: H_a: (3) p. 14; ‡: inequality reversed.
*: H_a: (2) p. 14; *: inequality reversed.

Table 6: Percentage (n) of choice patterns with ω^* by presentation order (within-subject).

Set	$\{\omega_p, \omega_£\} \to \{\omega_p, \omega_£, \omega^*\}$					$\{\omega_p, \omega_£, \omega^*\} \to \{\omega_p, \omega_£\}$				
	ω_p then ω_p	$\omega_£$ then $\omega_£$	ω_p then $\omega_£$	$\omega_£$ then ω_p	χ^2	ω_p then ω_p	$\omega_£$ then $\omega_£$	ω_p then $\omega_£$	$\omega_£$ then ω_p	χ^2
a	36 (18)	38 (19)	10 (5)	16 (8)	0.69	46.3 (25)	38.9 (21)	5.6 (3)	9.3 (5)	0.50
b	29.6 (16)	44.4 (24)	14.8 (8)	11.1 (6)	0.29	32 (16)	52 (26)	10 (5)	6 (3)	0.50
c	51.0 (26)	33.3 (17)	3.9 (2)	11.8 (6)	2.00	30.8 (16)	48.1 (25)	1.9 (1)	19.2 (10)	7.36***
d	34.7 (17)	40.8 (20)	10.2 (5)	14.3 (7)	0.33	40.7 (22)	42.6 (23)	14.8 (8)	1.9 (1)	5.44**
e	50 (26)	38.5 (20)	7.7 (4)	3.9 (2)	0.67	62.8 (32)	19.6 (10)	9.8 (5)	7.8 (4)	0.11
f	27.8 (15)	38.9 (21)	13.0 (7)	20.4 (11)	0.89	26.0 (13)	54 (27)	14 (7)	6 (3)	1.60
g	32 (16)	44 (22)	4 (2)	20 (10)	5.33**	40.7 (22)	35.2 (19)	7.4 (4)	14.8 (8)	1.33
h	25 (13)	59.6 (31)	7.7 (4)	7.7 (4)	0.00	27.5 (14)	47.1 (24)	9.8 (5)	15.7 (8)	0.69
i	46.3 (25)	29.6 (16)	9.3 (5)	14.8 (8)	0.69	48 (24)	34 (17)	12 (6)	6 (3)	1.00
j	42 (21)	40 (20)	4 (2)	14 (7)	2.78*	50 (27)	27.8 (15)	9.3 (5)	13.0 (7)	0.33
k	63.5 (33)	23.1 (12)	7.7 (4)	5.8 (3)	0.14	76.5 (39)	7.8 (4)	3.9 (2)	11.8 (6)	2.00
l	45.1 (23)	27.5 (14)	13.7 (7)	11.8 (6)	0.08	38.5 (20)	48.1 (25)	3.9 (2)	7.7 (4)	0.67
m	56.9 (29)	23.5 (12)	3.9 (2)	11.8 (6)	2.00	46.2 (24)	42.3 (22)	5.8 (3)	5.8 (3)	0.00
n	45.1 (23)	31.4 (16)	5.9 (3)	17.7 (9)	3.00*	42.3 (22)	46.2 (24)	5.8 (3)	5.8 (3)	0.00
Aggregate	41.8 (301)	36.6 (264)	8.3 (60)	12.9 (93)	7.12***	43.5 (316)	38.8 (282)	8.1 (59)	9.4 (68)	0.64

Notes. Subjects choosing the decoy not shown.

ω_p then ω_p: subject chooses ω_p in the first booklet and ω_p in the second booklet.

McNemar tests. One, two and three symbols indicate significance at $\alpha = 0.1$, 0.05 and 0.01.

*: H_a: $\Pr\left(\omega_p \in c(\{\omega_p, \omega_£\}) \text{ and } \omega_£ \in c(\{\omega_p, \omega_£, \omega^*\})\right) - \Pr\left(\omega_£ \in c(\{\omega_p, \omega_£\}) \text{ and } \omega_p \in c(\{\omega_p, \omega_£, \omega^*\})\right) \neq 0$.

Table 7: Percentage (n) choosing ω_p with ω^* (between-subject).

Set		No decoy		Decoy		χ^2
a	ω^*	51.0	(53)	51.9	(54)	0.02
b		41.4	(43)	41.4	(43)	0.00
c		52.4	(54)	47.6	(49)	0.49
d		43.7	(45)	51.9	(54)	1.41
e		64.1	(66)	63.1	(65)	0.01
f		36.5	(38)	44.2	(46)	1.28
g		47.1	(49)	50.0	(52)	0.24
h		37.9	(39)	35.0	(36)	0.19
i		54.8	(57)	60.6	(63)	0.71
j		54.8	(57)	57.7	(60)	0.18
k		79.6	(82)	74.8	(77)	0.69
l		54.4	(56)	49.5	(51)	0.31
m		58.3	(60)	60.2	(62)	0.21
n		49.5	(51)	55.3	(57)	0.70
Aggregate		51.8	(750)	53.1	(769)	0.62

Notes. χ^2 tests. One, two and three symbols indicate significance at $\alpha = 0.1$, 0.05 and 0.01.

*: H_a: $\Pr\Big(\omega_p \in c\big(\{\omega_p, \omega_£, \omega^*\}\big)\Big) - \Pr\Big(\omega_p \in c\big(\{\omega_p, \omega_£\}\big)\Big) \neq 0$.

Table 8: Percentage (n) of choice patterns with ω'_p and $\omega'_£$ by presentation order and as a function of the range effect (within-subject).

Set		Negative range effect										
		ω_p then ω_p	$\omega_£$ then $\omega_£$	ω_p then $\omega_£$	$\omega_£$ then ω_p	χ^2		ω_p then ω_p	$\omega_£$ then $\omega_£$	ω_p then $\omega_£$	$\omega_£$ then ω_p	χ^2
a	$\omega'_p \to \omega'_£$	23.3 (7)	56.7 (17)	20.0 (6)	0.0 (0)	$6.00^{\dagger\dagger\dagger}$	$\omega'_£ \to \omega'_p$	15.2 (5)	63.6 (21)	0.0 (0)	21.2 (7)	$7.00^{\dagger\dagger\dagger}$
f	$\omega'_p \to \omega'_£$	6.1 (2)	66.7 (22)	15.2 (5)	6.1 (2)	1.29	$\omega'_£ \to \omega'_p$	13.3 (4)	46.7 (14)	0.0 (0)	36.7 (11)	$11.00^{\dagger\dagger\dagger\dagger}$
k	$\omega'_p \to \omega'_£$	21.7 (5)	26.1 (6)	47.8 (11)	4.4 (1)	$8.33^{\dagger\dagger\dagger\dagger}$	$\omega'_£ \to \omega'_p$	38.9 (7)	33.3 (6)	0.0 (0)	27.8 (5)	$5.00^{\dagger\dagger}$
n	$\omega'_p \to \omega'_£$	22.2 (4)	61.1 (11)	16.7 (3)	0.0 (0)	$3.00^{\dagger\dagger}$	$\omega'_£ \to \omega'_p$	13.0 (3)	69.6 (16)	0.0 (0)	17.4 (4)	$4.00^{\dagger\dagger}$
Aggregate	$\omega'_p \to \omega'_£$	17.3 (18)	53.9 (56)	24.0 (25)	2.9 (3)	$17.29^{\dagger\dagger\dagger\dagger}$	$\omega'_£ \to \omega'_p$	18.3 (19)	54.8 (57)	0.0 (0)	26.0 (27)	$27.00^{\dagger\dagger\dagger\dagger}$
		Positive range effect										
		ω_p then ω_p	$\omega_£$ then $\omega_£$	ω_p then $\omega_£$	$\omega_£$ then ω_p	χ^2		ω_p then ω_p	$\omega_£$ then $\omega_£$	ω_p then $\omega_£$	$\omega_£$ then ω_p	χ^2
a	$\omega'_p \to \omega'_£$	71.4 (15)	0.0 (0)	0.0 (0)	23.8 (5)	$5.00^{\ddagger\ddagger}$	$\omega'_£ \to \omega'_p$	73.7 (14)	0.0 (0)	21.1 (4)	5.3 (1)	$1.80^{\ddagger}$
f	$\omega'_p \to \omega'_£$	79.0 (15)	10.5 (2)	5.3 (1)	0.0 (0)	1.00	$\omega'_£ \to \omega'_p$	81.0 (17)	4.8 (1)	4.8 (1)	9.5 (2)	0.33
k	$\omega'_p \to \omega'_£$	90.3 (28)	0.0 (0)	0.0 (0)	9.7 (3)	$3.00^{\ddagger\ddagger}$	$\omega'_£ \to \omega'_p$	90.6 (29)	0.0 (0)	9.4 (3)	0.0 (0)	$3.00^{\ddagger\ddagger}$
n	$\omega'_p \to \omega'_£$	40.6 (13)	37.5 (12)	3.1 (1)	18.8 (6)	$3.57^{\ddagger\ddagger}$	$\omega'_£ \to \omega'_p$	64.5 (20)	29.0 (9)	6.5 (2)	0.0 (0)	$2.00^{\ddagger}$
Aggregate	$\omega'_p \to \omega'_£$	68.9 (71)	13.6 (14)	1.9 (2)	13.6 (14)	$9.00^{\ddagger\ddagger\ddagger}$	$\omega'_£ \to \omega'_p$	77.7 (80)	9.7 (10)	9.7 (10)	2.9 (3)	$3.77^{\ddagger\ddagger}$

Notes. Subjects choosing the decoy not shown.
Negative and positive range effects are defined as subjects whose range effect ($\ln(p) \times \mathbb{1}_{\Delta'_p}$ in Table 3 p. 22 of the main text) is smaller or greater than the median.
ω_p then ω_p: subject chooses ω_p in the first booklet and ω_p in the second booklet.
$\omega'_p \to \omega'_£$: ω'_p added to $\{\omega_p, \omega_£\}$ in the first booklet and $\omega'_£$ in the second.
McNemar tests. One, two, three and four symbols indicate significance at $\alpha = 0.1$, 0.05, 0.01 and 0.001.
†: H_a: (1) p.14; ‡: inequality reversed.