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COMPETING FOR AFFECTION:
PERCEPTUAL FLUENCY AND AMBIGUITY SOLUTION

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DATA AVAILABILITY

Data, examples of stimuli, statistical models, and supplementary analyses and documents are available at https://osf.io/4dafs.

ABSTRACT

Human perceptual processes are highly efficient and rapidly extract information to enable fast and accurate responses. The fluency of these processes is reinforcing, meaning that easy-to-perceive objects are liked more as a result of misattribution of the reinforcement-affect to the object identity. However, some critical processes are disfluent yet their completion can be reinforcing leading to object preference through a different route. One such example is identification of objects from camouflage. In a series of 5 experiments, we manipulated object contrast and camouflage to explore the relationship between object preference to perceptual fluency and ambiguity solution. We found that perceptual fluency dominated the process of preference assessment when objects are assessed for "liking". That is, easier-to-perceive objects (high-contrast & non-camouflaged) were preferred over harder-to-perceive objects (low-contrast & camouflaged). However, when objects are assessed for "interest", the disfluent yet reinforcing ambiguity solution process overrode the effect of perceptual fluency, resulting in preference for the harder-to-perceive camouflaged objects over the easier-to-perceive non-camouflaged objects. The results have implications for preference and choice in a wide range of contexts by demonstrating the competition between perceptual fluency and ambiguity solution on preference, and by highlighting the critical factor of the form of preference decision.

KEY WORDS

- Perceptual fluency
- Aha
- Aesthetics
- Preference

PUBLIC SIGNIFICANCE STATEMENT

This study has implications for designers (artists, programmers, and advertisers) who wish to modify user behaviour by either increasing or decreasing user engagement with, or preference for, an object. For example, increasing attention towards a target to boost sales or decreasing likeability of a target as a health intervention. The presented experiments demonstrate that how much one likes and is interested in a visual target can be greatly influenced by how easy it is to perceive that target and whether or not one has to interact with it. We found that targets presented on a clear background were more likeable than those presented on a visual noisy background. However, the visual noise had the opposite effect on interest in the targets – that is targets on a visually noisy background were found more interesting that those on a clear background. These effects were enhanced when participants were required to respond to the target.

INTRODUCTION

Evolutionary pressure has produced highly efficient perceptual systems to enable rapid recognition and localisation of important objects (prey, predators, conspecifics etc.). However, detecting objects in complex background arrays remains a non-trivial task so such processes, when they are effective, are supported by reinforcement signals. In other words, because perceptual processes are so fundamental to an individual's survival, when target location and/or identification is successful and efficient, those processes are reinforced (e.g. Erle, Reber, & Topolinski, 2017; Ludmer, Dudai, & Rubin, 2011). This reinforcement can evoke a subtle pleasure response that may then be misattributed to the target object (see Reber, Schwarz, & Winkielman (2004) for a review). For example, manipulations that facilitate visual stimulus processing such as repeated stimulus presentation (the mere exposure effect, e.g., Zajonc, 1968), stimuli with greater contrast or longer presentations (e.g. Reber, Winkielman, & Schwarz, 1998), symmetrical stimuli (e.g. Bertamini, Makin, & Pecchinenda, 2013), possible Necker cubes (Topolinski, Erle, & Reber, 2015), and smooth motion (Flavell, McKean, et al., 2018) all aid object perception and increase the liking for the viewed object.

A clear prediction from this account is that the fluency with which an object is processed should predict object liking. However, there are situations in which a disfluent process might evoke a positive emotional response. Consider the problem of detecting camouflaged objects. The evolution of body features that closely match background features in the environment to reduce visibility is wide-spread and most evident in the evolutionary arms race between predators and prey. For example, the Peppered Moths' colouring has rapidly developed to match sooty and newly cleaned buildings (Cook, Grant, Saccheri, & Mallet, 2012), the tiger's stripes allow it hide in dappled forest shade (e.g. Cott, 1940), and the cuttlefishes' rapid colour and texture fluctuations allow it to remain concealed in a varied underwater environment (Messenger, 2001).

Detecting, or avoiding becoming, the next meal is then clearly dependent on solving the camouflage problem. Hence solving this ambiguous perceptual state is reinforcing for many animals and humans. Indeed imaging work has shown increased amygdala activity when objects were detected in an ambiguity solution task (Ludmer, Dudai, & Rubin, 2011) and many of us are aware of the pleasant feeling when finally perceiving the alternative image in an ambiguous figure such as the famous Necker cube (Necker, 1832) or Schröder stairs (Schröder, 1858). The term for this pleasant feeling from solving such ambiguous situations is the 'aha' moment (e.g. Muth, Raab, & Carbon, 2016; Topolinski & Reber, 2010). Although 'aha' typically involves high-level effortful cognitive processes (such as that described above), it can be evoked following automatic early perceptual processes that do not require high-level input. For example, a camouflaged stationary object that a participant has been searching for can be suddenly revealed using a principle such as common fate, when the object moves relative to its background. In this scenario, an early perceptual process automatically resolves the ambiguity problem and facilitates the 'aha'. Just as affect from fluent processing can be misattributed to a target object, the aha affect can also be misattributed and may override the effect on affect of disfluent target processing. Indeed Erle, Reber, & Topolinski (2017) found that objects perceived from only background features (disfluent processing of an ambiguous situation via Gestalt cues of good continuation and closure) were preferred over those perceived from outlines (fluent processing of an unambiguous situation). Contrary to the fluency account, such work demonstrates that positive affect can be misattributed to an object even when perceptual processes are disfluent.

In the current experiments, we examine the effects of, and potential conflict between, perceptual fluency and ambiguity solution on object preference. In these experiments, participants see an object move across a screen after a brief stationary period. The first manipulation is object contrast. Some objects will be high contrast (black on a pale grey background) while others will be low contrast (dark grey and pale grey background). This is a well-established manipulation of perceptual fluency which can affect processing time, judgements of liking and judgements of truth (e.g. Reber & Schwarz, 1999; Reber et al., 1998). The second manipulation is the presence of camouflage. Some objects will be presented on a blank background such that they are immediately visible (non-camouflaged), while others are embedded in a background of similar features such that they remain invisible until they begin to move (e.g., Uttal, Spillmann, Stürzel, & Sekuler, 2000; Watanabe, 2004). We predict that objects presented with greater fluency (i.e. higher contrast and no camouflage) will be preferred over those presented with lower fluency (i.e. lower contrast and camouflage).

The third manipulation is the presence/absence of a response task that demands a rapid response to a transient change in the target appearance. This task yields reaction times that will explicitly indicate the effect of perceptual fluency manipulations (Reber & Schwarz, 1999). We predict, for example, that reaction times to more fluent higher contrast stimuli will be shorter than those to less fluent low-contrast stimuli. As well as providing an indicator of processing fluency, the task itself may affect preference judgements by contributing to participants' moment-to-moment experience of fluency. Participants' ability to perform the response task will be affected by perceptual fluency, so participants who perform this task will have a different moment-to-moment experience of fluency than those who do not: that is, participants who perform the task will have a greater overall experience of the fluency of a trial than those who do not (Reber, Schwarz, et al., 2004; Reber, Wurtz, & Zimmermann, 2004). Because of this we predict that greater fluency feedback from performing the response task will lead to more extreme fluency effects on preference than if the response task were not performed.

Finally, a critical question is whether identifying a camouflaged object (ambiguity solution) is so reinforcing that it overrides the disfluent processing required to achieve it. It is here that the potential increased experience of fluency from the response task may be critical. That is, if the task is not performed then experience of fluency will be reduced which may result in preference for camouflaged over non-camouflaged objects.

EXPERIMENT 1

Experiment 1 was designed to test the effectiveness of our stimulus manipulations of perceptual fluency. Participants would see an object move across the screen and would be required to press a button as soon as the object makes a temporary size change. This reaction time (RT) task was undertaken in four conditions: i) high contrast without camouflage; ii) high contrast with camouflage; iii) low contrast without camouflage; and iv) low contrast and with camouflage. Video examples of stimulus motion in each experiment can be found at https://osf.io/4dafs. The contrast and camouflage variables determine the perceptual fluency of a trial. High contrast yields greater fluency than low contrast, and trials without camouflage yield greater fluency than those with camouflage (due to meta-contrast masking caused by identical features in the latter). As such, the 'high contrast without camouflage' condition has the greatest fluency of all conditions and the 'low contrast with camouflage' condition has the least fluency of all conditions. We predict that RTs will be related to fluency where the shortest RTs result from greatest fluency and the longest RTs result from least fluency.

METHOD

Apparatus. Participants sat at a table in a dimmed room facing a 23" touch screen monitor (HannsG (Taipei, Taiwan) HT231HPB, 1920×1080 pixels) at approximately 50 cm distance. A keyboard was positioned on the table between the participant and the screen. Participants and the keyboard spacebar were positioned at the screen's horizontal centre. Stimulus presentation (60Hz) and response recording were achieved using custom scripts and Psychtoolbox 3.0.11 (Brainard, 1997; Kleiner, Brainard, & Pelli, 2007; Pelli, 1997) operating within Matlab 2015a (The MathWorks Inc., Natick, USA) on a PC (Dell (Round Rock, USA) XPS, Intel (R) Core (TM) i5-4430, 3 GHz CPU, 12 GB RAM, 64 bit Windows 7).

Task. Participants completed a practice block and then a task block (the former intended as rehearsal for the latter). In each trial of the practice and task blocks an object would appear and move in a straight line across the screen. On some trials the target would temporarily increase in size during its movement. Participants were instructed to "tap a blue button on the screen if the object changes size" and to "try to respond as quickly and accurately as possible". Instructions were presented on the screen and verbally by the experimenter. Verbatim copies of the instructions given to participants are available at https://osf.io/4dafs. On some trials the object would be accompanied by a masking camouflage pattern.

Trial composition. See Figure 1A. At the start of a trial a blue response button would appear at the bottom centre of the screen (this would remain until the end of the trial). After 1000 ms a central fixation cross appeared for 500 ms. The cross would then disappear leaving only the response box for the next 500 ms. Then the object (and the camouflage pattern in appropriate trials) would appear and remain until the end of the trial. The object would remain stationary for 1000 ms before moving 150 mm in a straight line across the centre of the screen over 3000 ms at a constant velocity. The middle point of the object's trajectory was always the centre of the screen (Figure 1B). The object would halt at its final position for 250 ms before all stimuli disappeared and the trial ended.

Stimulus properties. The screen background was a constant pale grey throughout the experiment. The object was either 5, 7 or 9 sided (Figure 1C). Object geometries were generated at random (for every trial for every participant) with constraints on internal and external angles of ≥30°, minimum side lengths of ~13.5 mm, and total areas between ~2700 mm^2 and ~5401 mm^2. Each object was presented as an outline of dots ~1.4 mm in diameter. The minimum and maximum distance between dot centres was ~4.3 mm and ~7.1 mm. The object's position at the start of a trial was a random rotation about the screen centre at a distance of 75 mm (e.g. Figure 1A). The object's temporary size change (an increase of 30% for 200 ms) could occur either 1000 ms (early size change) or 2000 ms (late size change) into the object's movement. This varied target change time was employed merely to ensure participants' attention to the task which would otherwise be reduced if target change always occurred at a predictable time point. The camouflage pattern was a trial-by-trial pseudo-random arrangement of 2000 stationary dots that were the same size and colour as those forming the object in that trial. The effectiveness of this camouflage is demonstrated in Figure 1D where the same object is presented out of camouflage (left panel) and in camouflage (right panel).

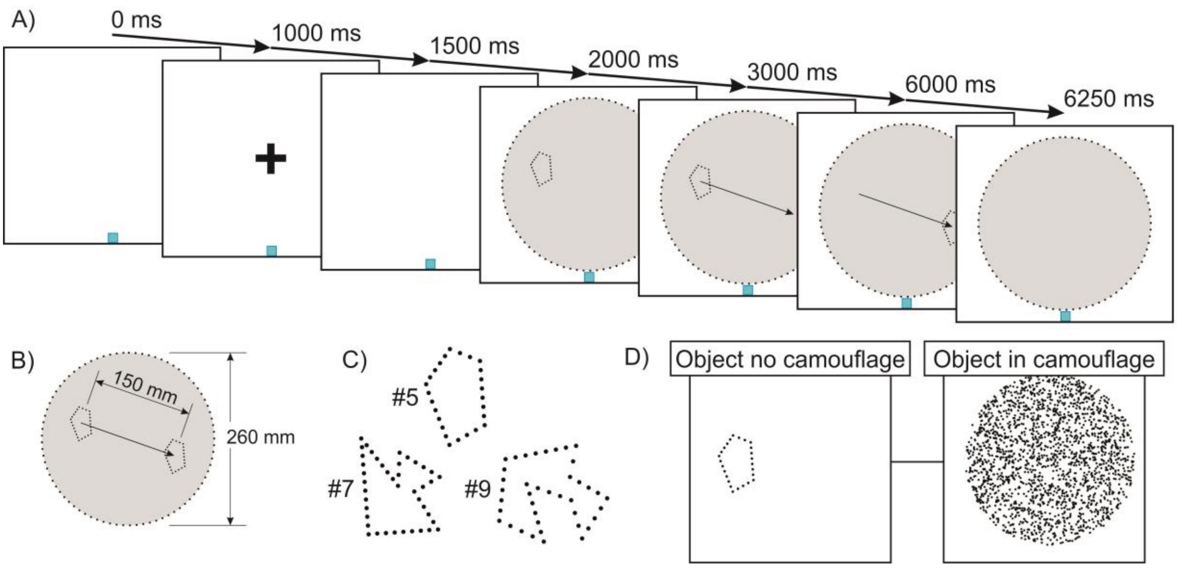

Figure 1. A&B) Schematic representations of a trial. The grey circle and its surrounding dots represent the maximum size of the camouflage display. The object is shown at its start and end positions with its motion path indicated by an arrow through the camouflage centre. The square at the bottom of the screen represents the response button. Note that these figures are for illustrative purposes and that during testing only the target object, response button and camouflage pattern (where appropriate) were visible on screen. We recommend that readers view the video examples of trials at https://osf.io/4dafs to fully appreciate the stimuli. C) Examples of 5, 7 and 9 sided objects. D) Examples of the same object in the same position in a no camouflage and in a camouflage condition.

Conditions. Every trial was determined from 4 conditions: camouflage on/off, size change early/late, contrast low/high, and object sides 5/7/9. There were six trials in the practice block (see https://osf.io/4dafs for details). In the task block, for each sided object (5, 7 or 9 sided), there were 14 camouflage trials and 14 non-camouflage trials. For each of those sets of 14, there were 7 low contrast trials and 7 high contrast trials. For each of those set of 7 trials, there were 3 early size change trials, 3 late size change trials, and 1 no size change trial. This yields 84 trials in total.

Data exclusion and analysis. Participants were removed from the analysis if they responded on >25% no size change trials, failed to respond on >25% of size change trials, or responded before the size change on >25% of appropriate trials. Individual trials were removed from analysis if that RT was >/< the mean±(3×SD) of that participant’s RT for that contrast × camouflage condition. Further, if more than 25% of RTs for any given contrast × camouflage condition were excluded then all trials for that participant were excluded. Lastly, participants were removed from analysis if any of their mean RTs for any given contrast × camouflage condition were greater than 750 ms. Data processing was completed using custom scripts in MATLAB 2018a (The MathWorks Inc., Natick, USA) and statistical analysis was conducted in JASP v0.9.1.0 (JASP-Team, 2018). In reporting the model we also provide the ‘evidence category’ of the Bayes factor determined by Wagenmakers et al. (2018). This is reported in italics following the model Bayes factor. Bayesian modelling for all experiments as well as frequentist versions of analysis are available at https://osf.io/4dafs. From those frequentist models we report the η^2 alongside the accepted Bayesian models reported here. The effect of the number of object sides (5, 7 or 9) and the time of size change (early or late) on RT and rating was not a principle question of the current manuscript so the included analysis does not consider it. However, for completeness, we provide this analysis at https://osf.io/4dafs.

Participants. Protocols were approved by the University of York’s Psychology Departmental Ethics Committee and were in accord with the tenets of the Declaration of Helsinki. A power analysis was conducted in G*Power 3.1.9.4 (Faul, Erdfelder, Lang, & Buchner, 2007) for a planned two-way repeated measures ANOVA with an expected medium effect size (partial η^2 = 0.05) and a targeted power of 0.8. This yielded a target sample of 28, but in an effort to maximize the robustness of our investigation we increased our target sample size to 40 as was the case in our earlier preference work (Flavell, McKean, et al., 2018; Flavell, Tipper, & Over, 2018). In Experiment 1, 41 participants were tested. One participant was removed from analysis because one contrast × camouflage condition mean RT (816 ms) exceeded the threshold of 750 ms. This left 40 participants (8 males, age mean ± SD = 20.3 ± 3). None of the remaining participants failed to respond on more than 5 of 72 (mean ± SD = .5 ± 1.1) size change trials and no participants responded on any of the 12 no change trials. No participant had more than 5 trials removed from analysis (mean ± SD = 1.8 ± 1.6). No participant completed more than one experiment.

RESULTS & DISCUSSION

Reaction times are shown in Figure 2. Two factor (contrast × camouflage) Bayesian repeated measures ANOVA on RTs support a model including only the two main terms (BF_{10} = 9.526+e17 [*extreme evidence for H_1 compared to H_0*], $p(H_1|\text{Data})$ = .711; contrast $BF_{incl.}$ = 2.887e+8 [η^2 = .65]; camouflage $BF_{incl.}$ = 4.633e+12 [η^2 = .673]).

Reaction times to changes in object size were as predicted: RTs were shorter when objects were high contrast than when they were low contrast ($BF_{10,U.}$= 4.096e+8); and RTs were shorter when objects were not camouflaged than when they were camouflaged ($BF_{10,U}$ = 5.325e+10). Interestingly the detrimental effect of low contrast was not compounded by that of camouflage. Following this confirmation that the tested stimulus properties do indeed affect perceptual fluency as expected, we can now explore the effect of perceptual fluency and ambiguity solution on object liking.

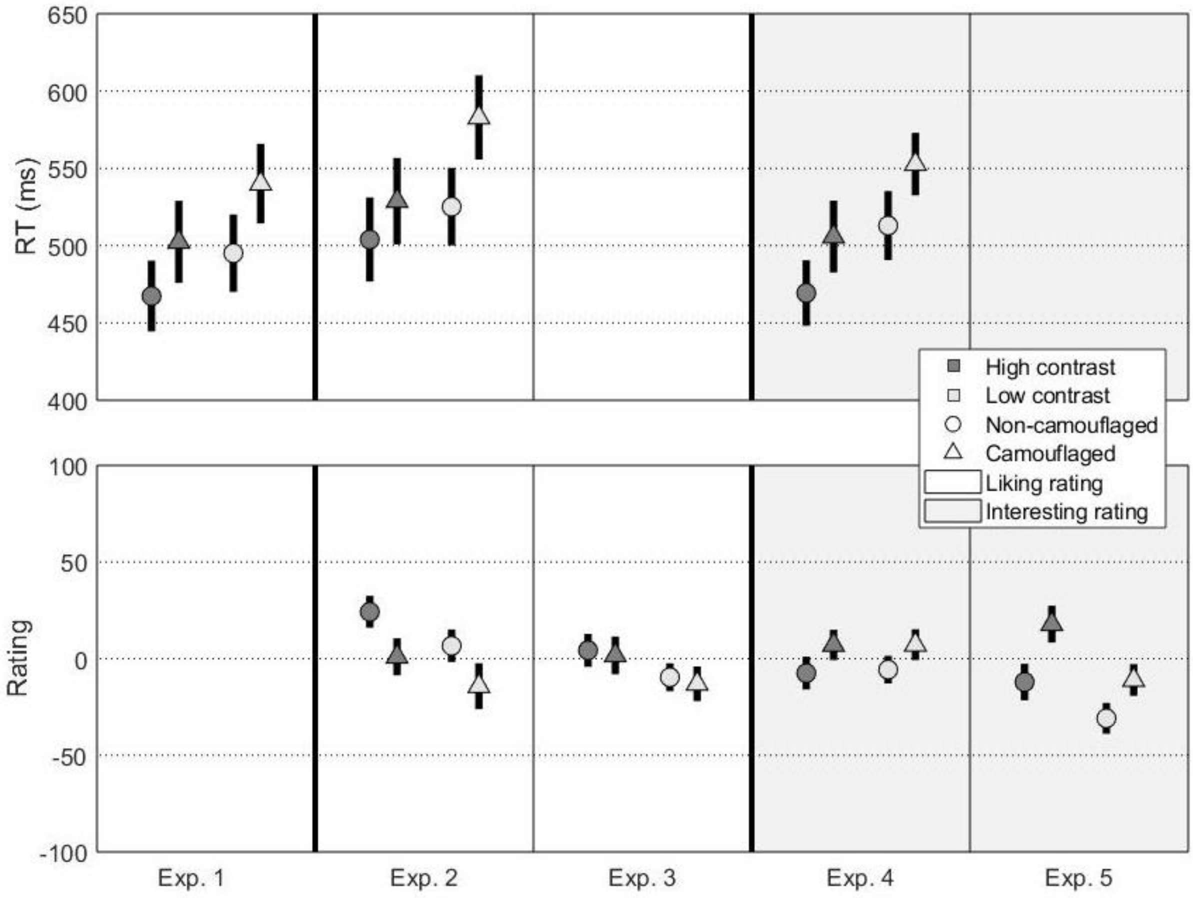

Figure 2. Mean (±95 confidence interval) reaction times to object size change (top panel) and ratings of the same objects (bottom panel) in each contrast × camouflage manipulation. In Experiments 2 and 3 objects were rated for 'liking' (white panels) and in Experiments 4 and 5 objects were rated for 'interest' (grey panels).

EXPERIMENT 2

Experiment 2 is a replication of Experiment 1 with the added task of rating the object for liking after each presentation. This experiment, therefore, allows participants maximum experience of fluency by requiring persistent attention and response to the object size change. As such it is strongly placed to provide insight into fluency and ambiguity solution effects on preference.

Because stimulus presentations are identical to those in Experiment 1, we expect to replicate the RT findings of faster responses in higher fluency conditions (i.e. high contrast / no camouflage). We also expect to replicate the well-established preference for high contrast objects over low contrast objects (e.g. Reber et al., 1998). However, the effect of camouflage on preference is less easy to predict. There are three possible results. First, perceptual fluency dominates so the camouflaged objects will be liked less than those that are not camouflaged. Second, the solution of detecting the camouflaged object is so rewarding that the camouflaged objects are liked more even though processing is disfluent. The third is that both fluency and ambiguity solution are highly rewarding and essentially cancel out the effects of one another. In this situation there may be no differences in liking ratings of camouflaged and non-camouflaged objects.

METHOD

Design. Experiment 2 is a replication of Experiment 1 with one difference – as well as responding to changes in object size, participants also rate each object for liking after presentation. After each presentation a 46 cm long Likert scale was presented horizontally in the centre of the screen for the participant to input their rating. The scale was a line with brackets at each end but no other demarcations. Participants were instructed to respond to object size change (as in Experiment 1) and to rate how much they liked the object. Participants were told to tap the scale towards the right if they liked the object, towards the left if they didn't, with how far left or right they tapped indicating how much they did or didn't like the object. As in Experiment 1, instructions were presented on the screen and verbally by the experimenter. Verbatim copies of the instructions given to participants are available at https://osf.io/4dafs. Only ratings on size change trials were included in analysis to mirror the analysis of RTs. For analysis, participant ratings (position on the scale) were transformed to fit a -100 to +100 range.

To maintain as close a replication of Experiment 1 as possible, the objects in this experiment were the same as those used in Experiment 1. That is, the first participant in Experiment 2 saw the same objects as the first participant in Experiment 1. Due to data exclusion, more participants were tested in Experiment 2 than its predecessor so new objects were generated for those participants.

Participants. 48 participants were tested. Eight participants were removed from analysis because their mean RT for at least one contrast × camouflage condition exceeded the threshold of 750 ms. This left 40 participants (12 males, age mean ± SD = 19.4 ± 2.2). No participant failed to respond on more than 8 of 72 (mean ± SD = 1±1.8) size change trials and no participants responded on any of the 12 no change trials. No participant had more than 11 trials removed from analysis (mean ± SD = 2.5 ± 2.2).

RESULTS & DISCUSSION

Reaction times and liking ratings are shown in Figure 2. Two factor (contrast × camouflage) Bayesian repeated measures ANOVA on RT data support a model including the two main terms and their interaction (BF_{10} = 7.982e+10 [*extreme evidence for H_1 compared to H_0*], $p(H_1|\text{Data})$ = .820; contrast $BF_{incl.}$ = 6.592e+5 [η^2 = .424]; camouflage $BF_{incl.}$ = 8.264e+6 [η^2 = .5245]; contrast × camouflage $BF_{incl.}$ = 18.28 [η^2 = .181]). Therefore, Experiment 2 replicates the RT findings of Experiment 1: longer reaction times for objects presented with lower fluency (i.e. low contrast and camouflage; contrast $BF_{10,U}$ = 74513, camouflage $BF_{10,U}$ = 3.319e+6). However, there was also a contrast × camouflage interaction (greater effect of camouflage on low contrast objects than on high contrast objects) that was not found in Experiment 1. Looking forward, results from Experiment 4 suggest that this interaction effect may be a false positive rather than an indication that stimulus processing is influenced by the dual task of response to object size change and object liking assessment.

Regarding liking ratings, a two factor (contrast × camouflage) Bayesian repeated measures ANOVA supports a model including only the two main terms (BF_{10} = 9.484e+8 [*extreme evidence for H_1 compared to H_0*], $p(H_1|Data)$ = .789; contrast $BF_{incl.}$ = 2.359e+3 [η^2 = .414]; camouflage $BF_{incl.}$ = 2.453e+6 [η^2 = .346]). Hence, the clear preference for high contrast objects ($BF_{10,U}$ = 3.634e+6) and for non-camouflaged objects ($BF_{10,U}$ = 422267) over their counterparts supports the hypothesis that perceptual fluency dominates assessments of liking. The finding that non-camouflaged objects were preferred over camouflaged objects also indicates that affect from ambiguity solution (identification of object in camouflage leading to an aha moment) is either ineffective at manipulating object liking in this context or that it is too weak to overcome the conflicting effect of perceptual fluency on object liking.

A key feature of this experiment is the detection of object size change response task that aims to increase experience of processing fluency. We have proposed that heightened experience of fluency will lead to a more extreme fluency effect on object preference. As such, by maintaining the same stimulus presentation but removing the response task we may expect that the liking ratings between conditions will differ less than they do here. The typically robust effect of contrast (preference for high contrast, e.g. Reber et al., 1998) should remain but perhaps in a diminished capacity. However, it is more difficult to predict the effects of camouflage in this new scenario. First, it is possible that, even though no response is required, fluency still dominates liking assessment because participants are still required to attend to the object (a disfluent process) for the liking assessment task. This would mean that non-camouflaged objects remain preferred as in the present experiment. Second, it is possible that when experience of the disfluency of perceiving a camouflaged target is reduced, the novelty of ambiguity solution will be sufficiently reinforcing to lead preference for camouflaged objects over non-camouflaged objects. Alternatively it may be that although experience of disfluency is reduced, it will be insufficiently reduced to allow the detection of ambiguity solution effects on preference.

EXPERIMENT 3

This experiment is designed to explore the effect of camouflage on object liking when experience of perceptual fluency is reduced (compared to the previous experiment). As such, Experiment 3 is a replication of Experiment 2 but without the object size change response task. The presented stimuli are exactly the same (including the temporary size change) but participants now only rate the presented object for liking. If the perceptual disfluency of perceiving a camouflaged object is dominant then non-camouflaged objects should be preferred whereas if ambiguity solution (identification of the object from the camouflage) is dominant then camouflaged objects should be preferred. Alternatively, both processes may be influence object liking in opposite directions leading to no preference differences between camouflaged or non-camouflaged objects.

METHOD

Design. Experiment 3 is a replication of Experiment 2 but now participants don't respond to changes in object size, and consequently, no RT exclusion criteria applied. Verbatim copies of the instructions given to participants are available at https://osf.io/4dafs.

Participants. Forty-one participants were tested. One participant failed to complete the experiment and was removed from the data set. The remaining sample consisted of 40 participants (4 male, age mean ± SD = 18.95 ± 1.36).

RESULTS & DISCUSSION

Liking ratings are shown in Figure 2. Two factor (contrast × camouflage) Bayesian repeated measures ANOVA on liking ratings support a model including only the contrast term (BF_{10} = 39.33 [*very strong evidence for H_1 compared to H_0*], $p(H_1|\text{Data})$ = .776; contrast $BF_{incl.}$ = 27.484 [η^2 = .194]). As expected (Reber et al., 1998), high contrast objects were still preferred over low contrast objects ($BF_{10,U}$ =

224.3) even without the response task that was required in Experiment 2. This was confirmed using a combined analysis of the liking ratings from Experiments 2 and 3 (Bayesian repeated measures ANOVA with within-subjects factors contrast and camouflage, and between-subjects factor of experiment). That is, the supported model included the three main terms and the interaction of experiment × camouflage (BF_{10} = 1.345e+9 [*extreme evidence for H_1 compared to H_0*], $p(H_1|Data)$ = .681; contrast $BF_{incl.}$ = 66032.457 [η^2 = .276]; camouflage $BF_{incl.}$ = 9627.525 [η^2 = .113]; experiment $BF_{incl.}$ = 16.877 [η^2 = .052]; experiment × camouflage $BF_{incl.}$ = 43.784 [η^2 = .065]) but, critically, did not include the interaction of contrast × experiment. Therefore, basic perceptual processing efficiency driven by contrast influences object liking regardless of the extra experience of fluency afforded by the response task. In sharp contrast, the presence or absence of overt responses significantly influenced liking ratings of camouflaged objects. Hence the preference effects driven by contrast and camouflage appear to be mediated by different processes, as the contrast is unaffected by the presence or absence of overt actions, while camouflage is clearly influenced by the action variable. One hypothesis is that the liking judgements of camouflaged objects are simultaneously influenced by both perceptual fluency and ambiguity solution. Reducing experience of perceptual fluency begins to reveal the weaker ambiguity resolution affect. Clearly, conclusions based on such a null result are limited, requiring new converging approaches.

One approach to the problem of revealing the reinforcing effects of identifying camouflaged objects is to take a different measure, one that might access a different property of object resolution from perceptual ambiguity. Several studies have shown that similar questions that appear to measure preference, such as whether a person is "liked" or "trusted", can in fact detect quite different underlying processes (e.g., Strachan, Kirkham, Manssuer, & Tipper, 2016). Therefore, the next experiment is a replication of Experiment 2 (i.e. the same stimuli are used) but the preference question is changed from "liking" to "interesting". Clearly both these questions measure a form preference (e.g. Ellsworth & Smith, 1988). For example, just as people may select to spend time with a person they liked more or purchase the art work they liked more, they may, similarly, choose to spend time with a more interesting person or buy more interesting art. Though related, these two measures would appear to access different aspects of preference (e.g. Berlyne, 1971; Silvia, 2006) where "liking" reflects pleasure from fluency and "interest" may reflect pleasure from reductions in disfluency (Graf & Landwehr, 2015, 2017). In the current studies, a suddenly identified camouflaged object represents such a reduction in disfluency. Therefore Experiment 4 is identical to Experiment 2, except that on each trial participants assess how interesting they found the object, rather than how much they liked it.

EXPERIMENT 4

METHOD

Design. Experiment 4 was a replication of Experiments 2 with a single difference. Rather than rate objects for 'liking', participants were instead instructed to '…rate how interesting you found the object…' both on screen and verbally by the experimenter. Similar to the preceding experiments, participants were told to tap the scale towards the right if they found the object interesting, towards the left if they didn't, with how far left or right they tapped indicating how interesting or not interesting they found the object. Verbatim copies of the instructions given to participants are available at https://osf.io/4dafs. Ratings were processed in the same way as that of Experiments 2 and 3.

Participants. 57 participants were tested Seventeen participants were removed from analysis because their mean RT for at least one contrast × camouflage condition exceeded the threshold of 750 ms. No participant failed to respond on more than 3 of 72 (mean ± SD = .5±.8) size change trials and no participant responded on any of the 12 no change trials. No participant had more than 7 trials removed from analysis (mean ± SD = 2.5 ± 1.8).

RESULTS & DISCUSSION

Reaction times and interest ratings are shown in Figure 2. Two factor (contrast × camouflage) Bayesian repeated measures ANOVA on RTs support a model including only those two main terms (BF_{10} = 2.836e+16 [*extreme evidence for H_1 compared to H_0*], $p(H_1|\text{Data})$ = .801; contrast $BF_{incl.}$ = 1.544e+11 [η^2 = .696]; camouflage $BF_{incl.}$ = 1.674e+8 [η^2 = .527]). The RT data of Experiment 4 resembles that of Experiments 1 and 2 – responses to high contrast objects are faster than those to low contrast objects ($BF_{10,U}$ = 2.512e+11), and responses to non-camouflaged objects are faster than to camouflaged objects ($BF_{10,U}$ = 1.947e+7). In Experiment 2 we found a contrast × camouflage interaction effect on RT that we speculated was either a result of the dual task (response to size change and assessment for liking) or a false positive finding. The absence of this interaction in the current experiment ($BF_{incl.}$ = 0.995) suggests that this was indeed likely to be a false positive resulting from *anomalously* long RTs in Experiment 2's low contrast camouflaged condition rather than a *meaningful* interaction.

Two factor (contrast × camouflage) Bayesian repeated measures ANOVA on interest ratings support a model including only the camouflage term (BF_{10} = 2.436e+5 [*extreme evidence for H_1 compared to H_0*], $p(H_1|Data)$ = .816, $BF_{incl.}$ = 169.076e+3; camouflage BF_{10} = 1.691e+5 [η^2 = .275]). The effect of contrast processing fluency has been robust in situations in which participants did (Experiment 2) and did not (Experiment 3) have heightened experience of the fluency with which camouflaged objects are processed via the response task. Such experience was available in the current experiment but modelling does not support any effect of contrast on interest ratings ($BF_{incl.}$ = 0.151). In other words, high contrast and low contrast objects were found equally interesting regardless of the accompanying camouflage condition. This null result was not anticipated. The influence of perceptual fluency evoked by higher contrast stimuli is well established and robust for preference decisions (as described by Reber et al. (1998) and Experiments 2 and 3 here). It is tempting to speculate that the ineffectiveness of contrast in the present experiment is the result of the new 'interest' question and that, simply, high contrast objects and low contrast objects are found equally interesting. However, by looking forwards to the Results and Discussion of Experiment 5 we see a re-appearance of the contrast effect on interest ratings. The lack of effect in the current experiment could therefore be an occasion when even robust effects are not always replicated.

The main purpose of this experiment, however, was to explore the effect of ambiguity solution on assessment of interest following a task that raised experience of the disfluency of perceptual processing. Recall that the RTs in Experiment 2 resulted from differences in each condition's overall perceptual fluency and that the participants' experience of fluency (provided by those RTs) completely predicted the pattern of liking ratings – the more rapidly processed non-camouflaged objects were preferred over the more slowly processed camouflaged objects. However, in the current experiment, we find a mismatch between RT and object interest. Camouflaged objects were processed more slowly than non-camouflaged objects but were still assessed as more interesting ($BF_{10,U}$ = 10900). Reduction in disfluency (the object identification from the camouflage) therefore appears to be an important factor in "interest".

Clearly it is important that we replicate and extend this finding of a new dissociation between perceptual fluency and a preference decision. Therefore, in the next experiment, we replicate Experiment 4 but remove the response task (as was the case for Experiment 3 following Experiment 2). Our interpretation of the contrast between the results of Experiments 2 and 3 make specific predictions concerning the camouflage effects in the upcoming Experiment 5. Note that camouflaged objects were liked less than non-camouflaged objects when a response to object size change was required (Experiment 2) but that there was no difference in liking when such a response was not required (Experiment 3). We suggested that both perceptual fluency and ambiguity solution were affecting preference in different ways. That is, in Experiment 3 the reduced experience of perceptual fluency (due to the missing response task) may have allowed the reinforcing effects of ambiguity solution to nudge liking for camouflaged to the point that both camouflaged and non-camouflaged objects were liked equally.

Though sound, this argument is based on a null finding so more positive converging evidence is required. Experiment 5 is designed to provide this by replicating Experiment 4 but without the response task. If it is the case that reducing experience of perceptual fluency (not completing the response task in this case) diminishes the influence of fluency on preference and thus relatively empowers the influence of object resolution, then we predict that the camouflage preference effect will be larger in Experiment 5 (without a response task) than in Experiment 4 (with a response task).

EXPERIMENT 5

METHOD

Design. Experiment 5 was a replication of Experiment 4 (interest ratings) but without the task of responding to object size change and, consequently, no RT exclusion criteria applied. Verbatim copies of the instructions given to participants are available at https://osf.io/4dafs.

Participants. 40 participants were tested (12 males, age mean ± SD = 20.4±1.3).

RESULTS & DISCUSSION

Interest ratings are shown in Figure 2. A 2 factor (contrast × camouflage) repeated measures Bayesian repeated measures ANOVA support a model including those two main terms (BF_{10} = 4.838e+13 [*extreme evidence for H_1 compared to H_0*], $p(H_1|Data)$ = .625; contrast $BF_{incl.}$ = 4.147e+7 [η^2 = .601]; camouflage $BF_{incl.}$ = 1.795e+8 [η^2 = .42]).

High contrast objects being found more interesting than low contrast objects ($BF_{10,U}$ = 1.201e+11) confirms the contrast effect on preference decisions that were observed in Experiments 2 and 3 and are reported in the wider literature (e.g. Reber et al., 1998). Given this, we interpret the null effect of contrast in Experiment 4 as a type 2 error, and conclude that the effect of contrast on preference is robust, generalising from "liking" to "interesting" dimensions of preference.

As in Experiment 4, camouflaged objects were judged to be more interesting than non-camouflaged objects ($BF_{10,U}$ = 1.029e+7). In discussing Experiment 4 we predicted that the camouflage effect would be larger in the present experiment and indeed this appears to be the case. A combined analysis of the interest ratings from Experiments 4 and 5 (Bayesian repeated measures ANOVA with within-subjects factors contrast and camouflage, and between-subjects factor of experiment) supported a model that included the camouflage × experiment interaction term (BF_{10} = 2.473e+22 [*extreme evidence for H_1 compared to H_0*], $p(H_1|Data)$ = .561; camouflage × experiment

$BF10_{incl.}$ = 12.077 [η^2 = .029]; see https://osf.io/4dafs for full model). These findings support our proposal that both perceptual fluency and ambiguity solution can simultaneously influence preference decisions in opposite directions, and that reducing experience of the former increases the effects of the latter.

GENERAL DISCUSSION

In this series of experiments, we have investigated a number of issues concerned with processes that determine preference decisions. To do this, we created a task in which participants see a target move across a screen under conditions of high/low contrast and with/without camouflage. Thus, manipulations of perceptual fluency and ambiguity solution were created. In some experiments, the presence of a reaction time task (response to temporary object size change) was used to enhance participants' experience of the disfluency of processing camouflaged targets. These manipulations allowed investigation of the effects on preference by perceptual fluency (from which more fluently processed objects may be preferred), and the ambiguity solution aha moment (from which less fluently processed objects may be preferred), and by the interaction of the two processes.

The reaction time task revealed that high contrast and non-camouflaged objects were processed faster than low contrast and camouflaged objects. Consistently shorter reaction times in the high contrast and non-camouflaged conditions than in the low contrast and camouflaged conditions (120 participants across Experiments 1, 2 and 3) confirmed that the contrast and camouflage manipulations affected perceptual fluency in the expected ways.

If, as many hypothesise, RT is a measure of perceptual fluency, and perceptual fluency is a predicator of liking then it stands to reason that RT and liking should be correlated. That is, shorter reaction times should correlate with higher responses. Experiment 2 was uniquely placed to test this[1]. In a supplementary analysis, we used generalised mixed-effects modelling in MATLAB 2018a (The MathWorks Inc., Natick, USA) with fixed-effects factors of 'contrast', 'camouflage', 'change time', and 'rating' (mean-centred) to predict RT. The model also included random-effects predictors enabling the intercept to freely vary across participants. A log link function was used to express the relationship between RT and the predictors such that linear changes in the predictor variables were associated with logarithmic changes in RT. Additionally, the inverse Gaussian distribution was used

[1] Only in Experiment 2 were both RTs and liking ratings taken. The same analysis was not developed for Experiment 4 because the interest rating appeared not to be predicted by fluency as the RTs were.

to parameterise dispersion in RT scores. Ratings were found to negatively correlate with RTs ($t(2774) = -2.1956$, $p = 0.028$, $d = -0.3472$, full model at https://osf.io/4dafs). That is, as RTs decreased (reflecting increased perceptual fluency) ratings of object liking increased. This is as expected from a fluency account of RT and liking preference.

The presence of the reaction time task was also used to manipulate experience of processing fluency for the liking ratings (Experiments 2 and 3). We found that experience of fluency had little effect on the contrast dimension of liking in that high contrast objects were liked more regardless of the experience state. Conversely, there was evidence that experience of processing fluency did affect the camouflage dimension of liking. That is, when experience of fluency was facilitated by the reaction time task in Experiment 2, camouflaged objects (lower fluency, slower to process) were liked less than non-camouflaged objects (higher fluency, faster to process). However, when experience of fluency was not facilitated in Experiment 3 (no reaction time task), the camouflage effect on liking was no longer observed. These results suggest that fluency dominates preference assessment when experience of fluency is facilitated (Experiment 2), but that other contradictory reinforces, such as aha, can influence preference when it is not facilitated (Experiment 3).

Basing conclusions on null results is undesirable, so we conducted two further experiments (Experiments 4 and 5) to explore a second dimension of preference – that of 'interest'. This relatively simple one-word change in the experimental procedure was used to explore the potential impact of aha on preference and it lead to dramatic change in the pattern of preference ratings. Graf & Landwehr's (2017) work on art appreciation showed that reductions in disfluency, due to on-going processing, lead to greater ratings of interest. In the current studies, searching for a camouflaged object is a disfluent process but its identification reduces disfluency and, in agreement with Graf & Landwehr's (2017) findings, interest in camouflaged objects was greater than in non-camouflaged (immediately apparent) objects. This difference in interest between camouflaged and non-camouflaged objects was even greater when the reaction time task was missing (Experiment 5) than when it was present (Experiment 4). The evidence from Experiments 2 and 3 (liking assessment) and Experiments 4 and 5 (interesting assessment) supports the notion of the simultaneous and contrasting effects of perceptual fluency and ambiguity solution on preference.

One model proposed to explain the two routes to aesthetic appreciation is based on the idea of initial automatic processing followed by more controlled processes (e.g, Graf & Landwehr, 2015). Hence an object can be preferred because automatic perceptual processes are more fluent; this is stimulus driven and the default mode of processing where a "gut reaction" detects emotional tone. In the current studies, such basic perceptual processes like contrast differences between figure and ground would automatically influence preference via different levels of perceptual fluency. The second route is assumed to require more controlled processes where the perceiver interacts actively with a stimulus to gain deeper understanding, such as initially thinking about a title for a work of art before assessment of interest, evaluating several dimensions (e.g., Carbon & Leder, 2005) or encouraging an exploratory mindset (Hansen & Topolinski, 2011). The appearance of a solution experienced as insight emerging from an analytic reflective system is often considered in complex and challenging situations such as problem solving in science, or art appreciation (e.g. Belke, Leder, & Carbon, 2015). In this context more complex and disfluent processing can result in greater preference when a solution is eventually discovered.

Our current findings support the potential role for more perceiver-driven controlled processes, where contrast between "liking" and "interesting" assessments are observed. In terms of the serial nature of stimulus elaboration observed in research where complex stimuli such as works of art are assessed, our current results might be somewhat different. That is, although responses to camouflaged objects are slower, these slower processes do not require active consciously controlled processes where resources are required to provide a solution to resolve ambiguity. Rather, the sudden emergence of the hidden object is a basic automatic perceptual process driven by early visual grouping properties such as common fate. The object appearance is completely independent of a participant's processing goals: as long as they observe the display, the object will spontaneously appear. As noted, for survival, such object detection processes have to be fast and automatic. Therefore, the two routes to preference based on perceptual fluency and ambiguity solution may have different properties, such as the important effect of the preference dimension assessed (liking vs interesting), but they do not necessarily differ in terms of automatic versus controlled stimulus processes.

This competition between fluency and ambiguity solution has implications for scenarios in which a range of designers (e.g. experimentalists, artists, programmers, or advertisers) may desire engagement with stimuli or products. We have shown that how an individual interacts with an object will determine how the properties of that object affect the experience of it. For example, generating an object with properties that are 'difficult to perceive' may result in greater interest if those properties can be resolved. But the designer runs the risk of putting off a consumer if those properties are sufficiently disfluent or the properties prove too difficult to resolve. That being said, it is possible to have the best of both worlds by camouflaging an image within an easy to perceive design. For example, the logo used for the Tour de France since 2003 (designed by Joel Guenoun in 2002, see http://www.joelguenoun.com/) is easily read but hides a cyclist riding a bike. The authors of the current text were familiar with the logo but were unaware of the camouflaged cyclist as it shared features with the background scene. Just as participants in our experiments did, the hidden object was eventually perceived and received the aha upon its discovery. In this case the same message concerning the event is promoted by both the initial fluency of processing and the subsequent emergence of the camouflaged object.

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