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Relative visual saliency differences induce sizable bias in consumer choice

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Abstract

Consumers often need to make very rapid choices among multiple brands (e.g., at a supermarket shelf) that differ both in their reward value (e.g., taste) and in their visual properties (e.g., color and brightness of the packaging). Since the visual properties of stimuli are known to influence visual attention, and attention is known to influence choices, this gives rise to a potential visual saliency bias in choices. We utilize experimental design from visual neuroscience in three real food choice experiments to measure the size of the visual saliency bias and how it changes with decision speed and cognitive load. Our results show that at rapid decision speeds visual saliency influences choices more than preferences do, that the bias increases with cognitive load, and that it is particularly strong when individuals do not have strong preferences among the options.

Keywords: Decision making; Reward; Visual saliency; Attention; Packaging; Consumer choice

Introduction

Over the last three decades psychologists and behavioral economists have documented a large number of ways in which individual judgments and choices depart from optimal decision making and information processing (Gilovich, Griffin, & Kahneman, 2002; Kahneman & Tversky, 2000; Bettman, 1979). Most of these departures from rationality, often called biases, are due to a limited capacity for processing information that is relevant to the decision problem (e.g., memories about previous experiences, attributes of the choice stimuli, or the probabilities of potential gains and losses). This often leads to overweighting some relevant variables at the expense of others.

Recent work in visual and decision neuroscience suggests that the way in which the brain processes low-level visual and value information might also lead to decision making biases (Krajbich & Rangel, 2011; Krajbich, Armel, & Rangel, 2010; Rangel, Camerer, & Montague, 2008; Shimojo, Simion, Shimojo, & Scheier, 2003). The logic for this new class of decision biases comes in two steps. First, a large body of work in visual neuroscience has shown that visual attributes of stimuli that affect their visual saliency, such as brightness or color, can affect the location and duration of fixations when individuals approach complex displays such as a vending machine or a supermarket shelf (Itti & Koch, 2001; Mannan, Kennard, & Husain, 2009). This visual saliency effect has been shown to persist for several fixations (Henderson, Weeks, & Hollingworth, 1999; Parkhurst, Law, & Niebur, 2002). As a result, more salient items are fixated on (i.e., looked at) longer than less salient stimuli. Second, a recent series of neuroeconomic studies have shown that the values assigned to stimuli at the time of choice depend on the amount of attention that they receive during the decision making process (Krajbich et al., 2010; Armel, Beaumel, & Rangel, 2008; Armel & Rangel, 2008; Shimojo et al., 2003). In particular, appetitive items receive higher liking ratings and are more likely to be chosen when attention focuses on them longer. Together, these two classes of findings suggest that everyday choices should be subject to visual saliency biases: independent of

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consumers' preferences, more visually salient options are more likely to be chosen due to the specific way in which the brain processes visual information.

We present the results of three real food choice experiments designed to resemble every-day supermarket choices. In Experiment 1 we test for the presence of a *visual saliency bias* and measure its magnitude as a function of the length of exposure to choice alternatives, i.e., at varying speeds of decision making. In Experiment 2 we examine how the bias is affected by conditions of cognitive load pervasive in every-day life, such as talking on a cell-phone while shopping. Finally, in Experiment 3 we seek to provide external validity for the visual saliency bias by utilizing button-press choices, which are similar to every-day vending machine button-press purchases.

Experiment 1: visual saliency bias in every-day consumer choices

While academics and practitioners alike acknowledge that physical design of packaging influences purchases, no systematic knowledge exists of why some visual features "work" and others don't. Further, we know little about the relationship between visual features and preferences, and how this relationship changes over time. This first experiment was designed to quantify the impact that exogenously controlled differences in visual saliency, in this case brightness of the food items, have on every-day food choices and how this effect changes over time.

Methods

We here introduce a novel experimental paradigm from visual psychophysics and neuroscience. Seven participants completed the experiment. They were asked not to eat for 3 h prior to the experiment, which had two parts. In the first part participants indicated their food preferences by ranking 15 snack food items (such as chips and candy bars) from 1 (most favorite) to 15 (least favorite). The rankings were used as a measure of subjective value for each item and participant.

In the second part, each participant made 1050 choices between pairs of foods (Fig. 1). Each trial began with an enforced 800 ms central fixation. Next, a blank screen was flashed for 200 ms. This is thought to "reset" the visual system, by clearing any latent information, and to increase the speed of visual processing (Fischer & Weber, 1993). Participants were then shown two different items, one on the left and the other on the right side of the screen. In order to simulate a crowded display, such as a vending machine, each item was surrounded by 8 other items. The experiment included 5 trials for each possible item pair and left–right spatial configuration.

We experimentally manipulated relative preferences and relative visual saliency as follows. The absolute difference in liking rankings between the two items (*d*) provides a measure of the strength of preference, where $d=1$ represents weak preference and thus difficult choice, while $d=14$ represents strong preference and thus easiest choice. The visual saliency of the two food items was manipulated by changing their relative local brightness (see Fig. 1). On each trial one of the two food items was made salient by decreasing the brightness of all other items to 65% (both the items surrounding the salient item and all items on the other side of the screen), while keeping the salient item's brightness at 100% so that it would visually "pop out"; i.e., be brighter than all other items.

To study how the visual saliency bias evolves with exposure time, food stimuli were displayed on the screen for 70, 100, 200, 300, or 500 ms. Presentation durations were kept constant in blocks of 105 trials. The block order was randomized across participants, and participants were given a short break between blocks.

Following the presentation of food items, a visual mask covered all the items (see Fig. 1). Visual masking is used frequently in vision science to stop any further visual processing, which allowed us to control the length of the exposure to the food items. The mask also signaled to participants that they should indicate their choice as quickly as possible by making an eye-movement towards the location of their preferred food item. At the end of the study, participants were asked to stay in the lab and were given to eat the food item that they chose in a randomly selected trial.

Gaze location was acquired from the right eye at 1000 Hz using an infrared Eyelink 1000 eyetracker (SR Research, Osgoode, Canada). Participants' heads were positioned in a forehead and chin rest. The distance between computer screen and participant was 80 cm, giving a total visual angle of $28° \times 21°$. The images were presented on a computer monitor using Matlab Psychophysics toolbox and Eyelink toolbox extensions (Brainard, 1997; Cornelissen, Peters, & Palmer, 2002). Left or right food choices were determined when an eye-movement was initiated and crossed a threshold of 2.2° from the center of the screen toward the left or the right food item. Response times are measured as the time from stimuli offset to response initiation.

About the experimental design

Several features of the experimental design, which are not common in the consumer research literature, are worth emphasizing. This is not a traditional eye-tracking study. In particular, we do not collect and analyze sequences of gaze data since the only recorded eye movements are those used to indicate choices, at which time the trial ends. Despite this, the eye-tracker plays a critical role in the experimental design.

First, it is used to enforce an 800 ms fixation to the central fixation cross at the beginning of every trial. In particular, the choice alternatives are not displayed on the screen until fixation at the center of the screen has been verified by the eye-tracker. This is critical because visual saliency depends on the relative position of the subsequent stimuli with respect to the current location of fixation. Thus, if participants had been allowed to move their eyes freely during this time, we would have lost experimental control over our relative saliency manipulation.

Second, using the eye-tracker to record choices allows us to collect less variable measures of decision time. The intuition for why this is the case is simple. Standard measures of decision times, such as response times measured by a button press, are

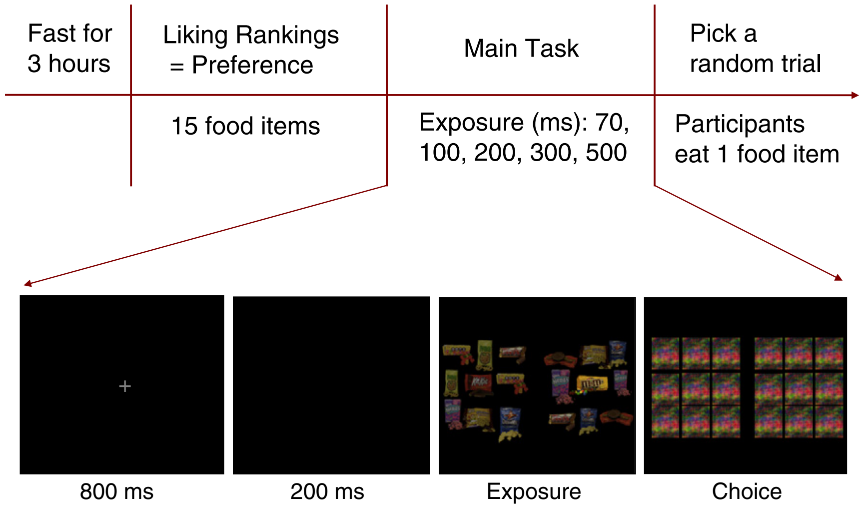

Fig. 1. Experiment 1. Hungry participants were asked to quickly decide whether they want to eat the left or the right central food item and to indicate their choices by looking toward the side of the screen where the chosen item was displayed. The saliency of one of the central items was enhanced by making it brighter, which caused it to "pop out" on the screen.

made up of two components: the time to decide and the time that it takes to implement the motor action used to indicate the choice. As a result, they have two sources of variability. By recording a decision as soon as an eye movement has been initiated, we can improve the precision of our measures of decision times since any variability of the time that it takes to execute the motor plan is eliminated.

Finally, we collect data on a very large number of trials within participants, but only for a handful of participants, which is standard practice in visual psychophysics and neuroscience. The rationale is simple: this allows the researchers to characterize the value of the parameters for each individual participant with great precision. Furthermore, a small number of participants are sufficient because there is often limited variation on the estimated properties of the underlying systems across participants.

Results

Mean response times by display duration were 317±31 ms (70 ms exposure), 348±43 ms (100 ms exposure), 281±35 ms (200 ms exposure), 306±37 ms (300 ms exposure), and 226±10 ms (500 ms exposure). A repeated measures ANOVA did not revealed a significant effect of display duration on response time ($F=1.56$, $p>.22$).

Fig. 2a shows the percent of correct choices (i.e., how often participants chose their preferred food items as indicated by reported rankings at the beginning of the experiment) as a function of (1) exposure time shown on the X-axis, (2) strength of preference (i.e., the difference in ranking: strong=high brand dominance if $d \geq 7$ and weak=low brand dominance if $d<7$), and (3) the presence of conflict between preference and visual saliency (i.e., conflict occurs when one item is more liked, but the other item is visually more salient). In the easiest condition (i.e., strong preference, high saliency of the preferred item, and longest exposure duration) participants chose their preferred items 90.4% of time. A 3-way repeated measures ANOVA with no interaction effects showed significant effects of:

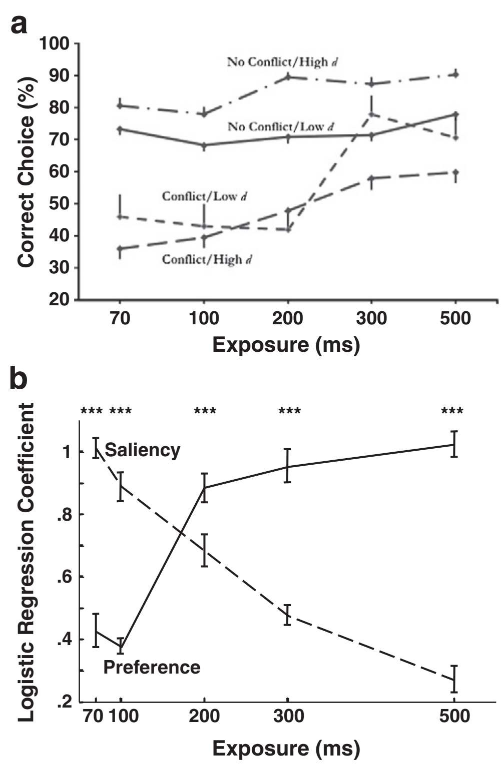

Fig. 2. Visual saliency bias in every-day consumer choice. (a) The percent of correct choices as a function of exposure, strength of preference, and whether or not there was a conflict between the preference and visual saliency. "No Conflict" denotes trials where the preferred food item is also more salient. "Conflict (high d)" includes trials where one of the two items is more liked but the other is more salient, and there is a strong prior preference for one of the items. "Conflict (low d)" refers to conflict trials where the strength of preference for one of the items is small. Error bars show S.E.M. (b) Estimated logistic regression coefficients for the relative preference and visual saliency as a function of exposure time. Error bars represent S.E.M. (***p<.001).

exposure time ($F=10.09$, $p<.00001$), strength of preference ($F=72.85$, $p<.00001$), and presence or absence of conflict between saliency and preference ($F=265.64$, $p<.00001$). Thus, participants were better at choosing their preferred food items as exposure time increased, when they had strong rather than weak preference for one of the two items, and when their preferred food items were also visually more prominent.

Next, we assessed the effects of preference and saliency on choice and how this relationship changes over time. We performed a mixed effects logistic regression of the probability of choosing the left item on its relative liking ranking (1 if left item is preferred and 0 otherwise) and its relative visual saliency (1 if left item is more salient and 0 otherwise). Fig. 2b shows the estimated coefficients for the relative preference and saliency variables as a function of exposure length (the regression was estimated separately at each exposure length). The influence of saliency on choice is dominant early on, at exposures of <200 ms ($p<.00001$, two-tailed t-test), but preference becomes the dominant influence after 200 ms ($p<.00001$, two-tailed t-test). Critically, however, saliency had a significant positive effect on choices at all exposure durations, even at 500 ms ($p<.02$; two-tailed t-test).

Finally, we examined how the influence of saliency vs. preference on choice depends on the underlying strength of preference. Fig. 3 depicts the choice patterns for conflict trials, in which one item is more liked but the other is more salient. When consumers have strong prior preference for a particular brand (Fig. 3a), they are quite good at identifying and choosing that brand rapidly: starting at 300 ms exposures, consumers are already choosing their preferred items over 70% of time even when these items are not visually prominent and are actually quite difficult to spot. However, in situations of brand parity (Fig. 3b), when the available brands are all pretty similar, consumers are influenced much more by visual features of the food items and end up choosing items that are visually prominent at least 40% of time even though this is inconsistent with their prior preferences.

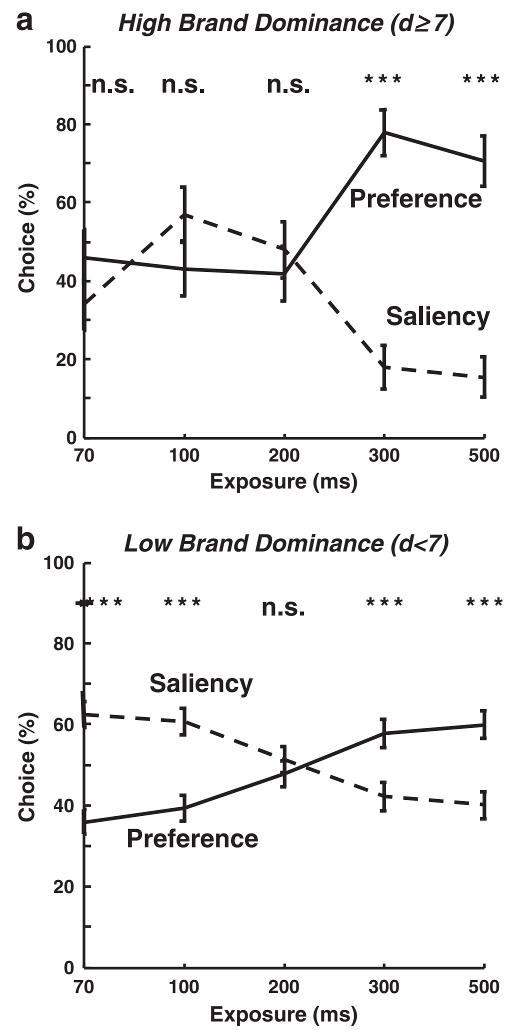

Fig. 3. Percent of choices on conflict trials (where one item is preferred but the other is more salient) for (a) easy choices with strong preferences for one of the items ($d\geq 7$) and (b) difficult choices with weak preference ($d<7$). Error bars represent S.E.M. (***$p<.001$).

Discussion

The results of Experiment 1 demonstrate a significant *visual saliency bias* in choices, which is dominant at very fast exposure times and persists even at longer exposure times. For example, the results show that at the shortest exposure times, visual saliency had over 200% more impact on choices than a 1-point increase in relative rankings, and the effect was still around 25% for the longest durations. Further, the bias is especially strong when participants' relative preferences between the two items are relatively weak, as is likely to be the case in many real world choices where market competition generates large numbers of similarly attractive options.

Experiment 2: visual saliency bias under cognitive load

Many every-day choices are made while decision-makers are engaged in alternative cognitively demanding tasks. For example, while purchasing a bag of chips in a grocery store, it is very likely that the consumer will also engage in additional tasks, such as a phone conversation or attending to a child that came along for the trip. Drolet, Luce, and Simonson (2009) recently suggested that such conditions of cognitive load do not necessarily make our choices worse, but rather increase the importance of externally available information. This provides motivation for our next experiment, since it suggests that visual saliency bias might become even more important under conditions of cognitive load. Experiment 2 examined this issue by introducing cognitive load into the previous experimental design.

Methods

Five participants completed this experiment, which is very similar to the previous one, except for the addition of a cognitive load task. On every trial the central fixation cross changed its color to either red or green. Participants were instructed to start each block of trials with a score of 50 and add 1 to the score each time the cross turned green, and subtract 1 each time it turned red. As before, they were also asked to make a choice as soon as the visual mask appeared on the screen by moving their eyes to the preferred item's location. To accommodate the added cognitive demands of the task, items were now displayed at 100, 300, 500, 1000 and 1500 ms.

Results

Mean response times were 468±50 ms (100 ms exposure), 371±40 ms (300 ms exposure), 282±25 ms (500 ms exposure), 292±27 ms (1 second exposure), and 279±9 ms (1.5 seconds exposure). A repeated measures ANOVA revealed a significant effect of display duration on response time ($F=4.86$, $p<.01$). Post-hoc multiple comparisons performed using Tukey's HSD test show that choices after 100 ms exposure were significantly slower (468±50 ms) than those at 500 ms (282±25 ms), 1000 ms (292±27 ms) and 1500 ms (279±9 ms) exposures.

All participants were able to perform the cognitive overload task, with performance improving as the length of exposure increased. The differences between participants' responses and correct answers (participants kept a count starting at 50 and could end as low as 30 or as high as 70) were 5.2 for 100 ms, 2.1 for 300 ms, 2.2 for 500 ms, 1.7 for 1000 ms, and 0.8 for 1500 ms (repeated-measures ANOVA, $p=.056$).

Fig. 4a shows the percent of correct choices as a function of the length of exposure, strength of preference, and saliency vs. preference conflict. In the easiest condition (i.e., strong preference, high saliency of the preferred item, and longest exposure duration) participants chose their preferred items 92.0% of time. A 3-way repeated measures ANOVA with no interactions showed significant effects of: exposure duration ($F=36.98$, $p<.00001$), strength of preference, i.e., choice difficulty ($F=51.45$, $p<.00001$), and presence or absence of saliency-value conflict ($F=165.83$, $p<.00001$), all in the expected directions.

Fig. 4b depicts the estimated logistic regression coefficients for relative saliency and preference as a function of the exposure duration. The influence of preference on choice peaked later than without cognitive load (at 1500 ms here vs. 200 ms in Experiment 1; $p<.00001$, two-tailed t-test). Critically, the influence of saliency on choice remained strong at all exposure durations ($p<.00002$; two-tailed t-test).

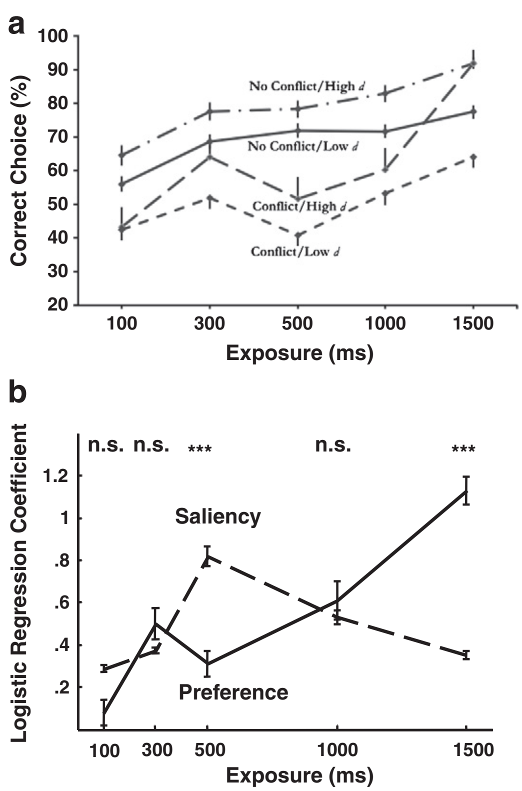

Fig. 4. Visual saliency bias under cognitive load. (a) The percent of correct choices as a function of exposure, strength of preference, and whether or not there was a conflict between the preference and visual saliency. Error bars show S.E.M. (b) Estimated logistic regression coefficients for relative preference and visual saliency as a function of exposure time. Error bars represent S.E.M. (***$p<.001$).

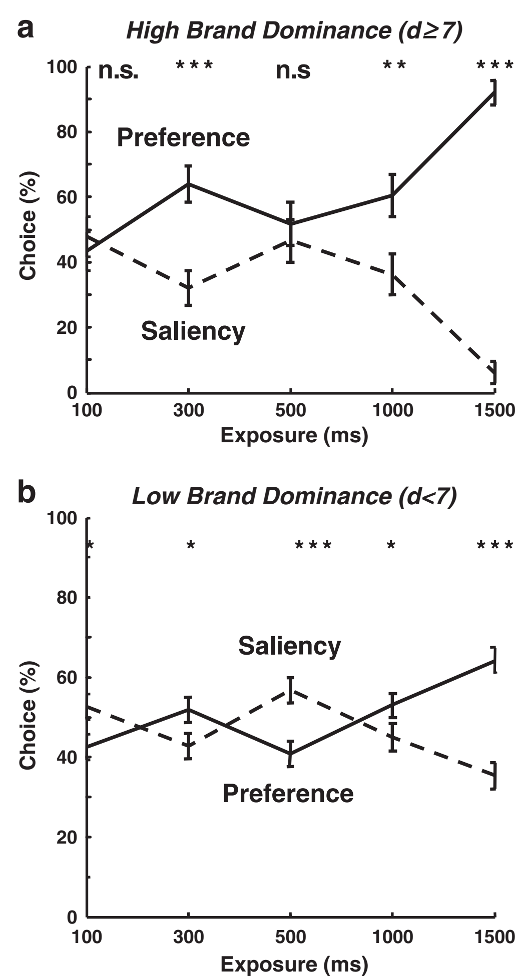

Fig. 5. Percent of choices on conflict trials (where one item is preferred but the other is more salient) for (a) easy choices with strong preferences for one of the items ($d\geq7$) and (b) difficult choices with weak preference ($d<7$). Error bars represent S.E.M. (***$p<.001$).

Finally, we examined how the influence of saliency vs. preference on choice depends on the strength of preference. Fig. 5 shows conflict trials, where one item is more liked but the other is more salient. Only once the exposure duration reached 1.5 s did preference clearly take over, and it did much more so for high brand dominance (Fig. 5a) than in the condition of low brand dominance (Fig. 5b).

Discussion

The results of Experiment 2 show that the visual saliency bias is longer-lasting, and relatively stronger, in the presence of cognitive load. For example, at stimuli exposures of 500 ms, the impact of visual saliency was over 200% stronger than that of a 1-point increase in the liking rankings. Importantly, the visual saliency bias was still significant and sizable at exposure times as long as 1500 ms.

One striking aspect of the data, which we were surprised by, was that the effect of saliency on choice did not decrease monotonically with exposure time (see Fig. 4b). We have the following post-hoc explanation for why this is the case. In previous work (Krajbich et al., 2010) we have shown that these types of choices seem to be made through a temporal integration model that looks like an attention modulated version of the Drift-Diffusion-Model (Ratcliff & Smith, 2004; Ratcliff & McKoon, 2008). One critical feature of these models is that early on in the integration process there is a lot of noise in the identification of the best item. As a result, early on, the choices are not significantly related to any of the underlying variables driving the computation and comparison of values. From this perspective, the data for Experiments 2 and 3 (discussed next) suggests that the cognitive load manipulation is slowing down the comparator process, and thus the effect of both saliency and preference is showing up later than in Experiment 1.

Experiment 3: external validity of visual saliency bias under cognitive load

One concern with the previous two experiments is that participants indicated their choices with eye movements. Experiment 3 extends the results to the case of hand movements, another motor modality that is representative of every-day behavior (e.g. a button press during vending-machine purchases).

Methods

The study follows the same procedure as Experiment 2, except that now participants were asked to indicate their choices by pressing the left or the right arrow key on the keyboard to indicate the location of the preferred item on the screen. The same five participants from Experiment 2 completed this task.

Results

Mean response times were 498±11 ms (100 ms exposure), 343±8 ms (300 ms exposure), 299±7 ms (500 ms exposure), 296±10 ms (1000 ms exposure), and 321±9 ms (1500 ms exposure). A repeated measures ANOVA revealed a significant effect of exposure duration on time that it took to indicate choices ($F=4.49$, $p<.01$), but a post-hoc Tukey's HSD test shows that this result is driven by the fact that the fastest exposure duration (100 ms) is significantly different from the three other conditions (500 ms, $p<.05$; 1000 ms, $p<.05$; and 1500 ms, $p=.05$). None of the other comparisons was significantly different from one another.

The difference between participants' responses and correct answers for the cognitive overload task shows that participants were able to perform the task well in all conditions (per block score: 1.7 for 100 ms, 2.5 for 300 ms, 3.1 for 500 ms, 2 for 1000 ms, and 1.3 for 1500 ms; repeated-measures ANOVA, $p=.581$).

Fig. 6a shows the percent of correct choices as a function of exposure time, strength of preference, and presence of the saliency vs. preference conflict. In the easiest condition (i.e., strong preference, high saliency of the preferred item, and longest exposure duration) participants chose their preferred items 92.7% of time. As in previous experiments, a 3-way repeated measures ANOVA with no interactions showed that the three variables had a significant impact on accuracy: exposure duration ($F=45.23$, $p<.00001$), strength

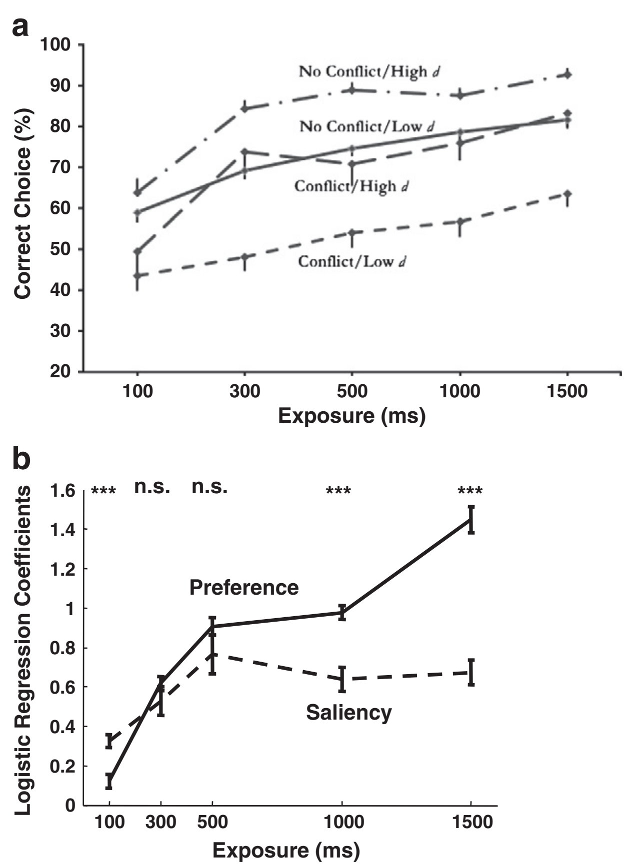

Fig. 6. External validity for visual saliency bias under cognitive load. (a) The percent of correct choices as a function of exposure, strength of preference, and whether or not there was a conflict between the preference and visual saliency. Error bars show S.E.M. (b) Estimated logistic regression coefficients for relative preference and visual saliency as a function of exposure time. Error bars represent S.E.M. (***$p<.001$).

of preference, i.e. choice difficulty ($F = 13.21$, $p < .00001$), and conflict ($F = 204$, $p < .00001$).

Fig. 6b depicts the estimated logistic regression coefficients for saliency and preference as a function of exposure time. The analysis shows that preference did not become the dominant factor influencing choice until 1000 ms ($p < .00001$, two-tailed t-test). As before, the influence of visual saliency on choice remained significant at all exposure durations ($p < .00002$; two-tailed t-test).

Finally, we once again found a strong effect of preference on choices under conditions of high brand dominance, i.e., strong preference (Fig. 7a). Still, it is worth noting that even then a significant fraction of choices favored the visually more prominent items, even though this was inconsistent with participants' preferences. At the same time, the visual saliency bias gained strength under conditions of low brand dominance, i.e., weak preference (Fig. 7b).

Discussion

The results of this final experiment show that the *visual saliency bias* is still significant and sizable when choices are

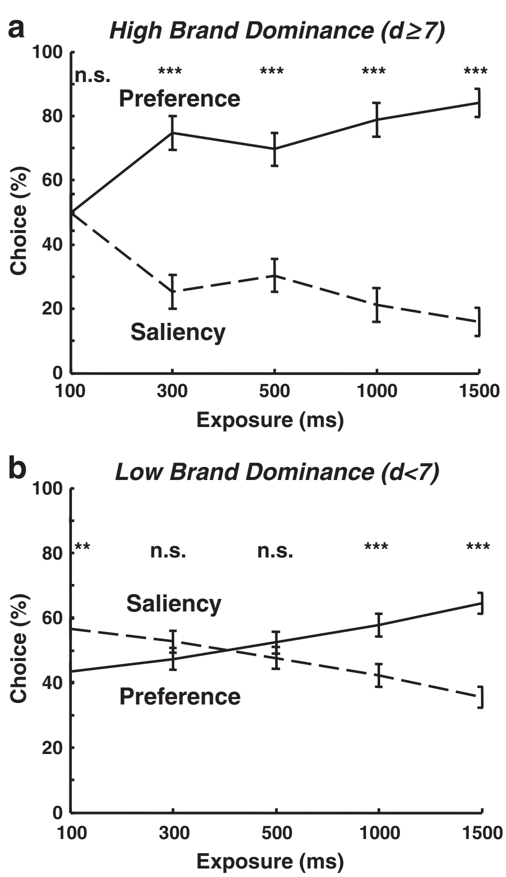

Fig. 7. Percent of choices on conflict trials (where one item is preferred but the other is more salient) for (a) easy choices with strong preferences for one of the items ($d \geq 7$) and (b) difficult choices with weak preference ($d < 7$). Error bars represent S.E.M. (***$p < .001$).

indicated with button-presses, thus providing external validity for the results from Experiments 1 and 2.

General discussion

These results provide evidence for the existence of a sizable visual saliency bias, especially under the conditions of rapid decision making and cognitive load that characterize everyday decisions, such as many supermarket purchases. It is important to emphasize that our results are not due to the use of unusually fast decision speeds. For example, recent studies of choice using similar food stimuli found that participants typically make these types of decisions in 500–2000 ms (Krajbich et al., 2010; Hare, Camerer, & Rangel, 2009; Litt, Plassmann, Shiv, & Rangel, 2009). Another study found that participants could make accurate choices in less than 3 seconds in displays that included 16 items (Reutskaja, Nagel, Camerer, & Rangel, 2010). Note that these response times are measured from the time of stimulus presentation, whereas the response times reported above only include the time from stimuli offset to response initiation. Thus, the decision times in this paper are commensurate with those previously reported.

The results have implications for our understanding of marketing and consumer choice. First, the results identify a novel neurally-plausible mechanism through which marketing practices, such as the color of packaging or how the store shelf is lit, could have a sizable impact on individual decisions, even when those practices are not correlated with the consumers' preferences. Although the magnitude of the visual saliency bias amounts to less than a 1-point increase on the liking ranking scale at the longest exposures, this impact on choices can translate to large profits in competitive marketplaces where the profit margins are tight and participants can choose among many highly liked options. Second, the results advance our understanding of the mechanisms through which *task-irrelevant* cues, such as the relative visual saliency of objects, can affect choices (for other channels see Kotler, 1973; North, Hargreaves, & McKendrick, 1997; Dijksterhuis, Smith, van Baaren, & Wigboldus, 2005).

An important direction for future work is to understand which concrete visual features trigger visual saliency biases. For example, would it be possible to trigger this type of biases by introducing a low-brightness, mild-color package in a domain in which all competing products have red bright packages? Fortunately, our current understanding of the visual system allows us to extrapolate from our data to address questions like this. It is well known that the most prominent visual features (e.g., colors, brightness) in a given scene (e.g., a supermarket shelf) determine the visual saliency of items (e.g., bags of chips). This is the case because neurons at the retina, superior colliculus, lateral geniculate nucleus and early visual cortical areas are particularly tuned to such simple visual features. Visual saliency then causes certain items to "pop out" of a visual scene, leading to automatic attention toward these items (Koch & Ullman, 1985; Itti & Koch, 2001; Mannan et al., 2009). This automatic, bottom-up attention works based on the center-surround principle: what matters for attention is feature contrast rather than absolute feature strength, e.g., a very bright item set against dimmer surroundings, or vice versa a dark item set against a bright background, will “pop out”. This suggests that what matters is to be visually different from the local surroundings, which induces an interesting problem of strategic competition in package design among competing brands.

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