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Gaze bias: Selective encoding and liking effects

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People look longer at things that they choose than things they do not choose. How much of this tendency—the *gaze bias effect*—is due to a *liking effect* compared to the information encoding aspect of the decision-making process? Do these processes compete under certain conditions? We monitored eye movements during a visual decision-making task with four decision prompts: Like, dislike, older, and newer. The gaze bias effect was present during the first dwell in all conditions except the dislike condition, when the preference to look at the liked item and the goal to identify the disliked item compete. *Colour content* (whether a photograph was colour or black-and-white), not decision type, influenced the gaze bias effect in the older/newer decisions because colour is a relevant feature for such decisions. These interactions appear early in the eye movement record, indicating that gaze bias is influenced during information encoding.

Keywords: Decision making; Eye movements; Gaze bias; Liking; Selective encoding.

When we make decisions we often spend longer examining options that we ultimately choose than those we do not choose (Pieters & Warlop, 1999). For example, when choosing a spouse, most people spend more time dating the person they ultimately marry and, when buying a car, one spends more time test-driving or reviewing features of the car they ultimately buy. How much of this is due to a *liking effect*—people's tendency to spend more time on things they like—and how much of it is due to a tendency that is part of the

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general decision-making process? Are there conditions under which these two tendencies compete to influence behaviour?

In the present study we used eyetracking methods to measure how long people look at two photographs in a two-alternative forced choice task with various decision prompts. Eyetracking provides millisecond-to-millisecond data about people's looking behaviour (Rayner, 1998, 2009) as they make decisions about visual stimuli (Wedel & Pieters, 2007), allowing us to examine at what time in processing (early encoding stages or late postencoding stages) different decision prompts affect the way people process information. Being able to examine the decision-making process as it evolves quickly over time in a task that draws upon cognitive processes that are easily measurable might inform us about the processes underlying those decisions, as well as others.

Some recent studies have investigated the time course of the decision-making process using eyetracking methods. Shimojo and colleagues (Shimojo, Simion, Shimojo, & Scheier, 2003; Simion & Shimojo, 2006, 2007) showed subjects two pictures of faces and asked them which one they thought was more attractive (like), less attractive (dislike), or rounder (objective decision). They found that subjects looked longer at the face that they ultimately chose—referred to as the *gaze bias effect*—regardless of the decision type, with the effect being most pronounced in the like condition, which they termed the *gaze cascade effect*. They analysed the data using *gaze likelihood curves*, which consist of plotting the probability of looking at a given item across time. These gaze likelihood curves consist only of the last 1.6 s of the trial, time-locked from the response backward in time (we will discuss the gaze likelihood measure in more detail in the Results section; see also Glaholt & Reingold, 2009b). Using this analysis, they found that this gaze bias evolved over time—subjects initially looked equally at the two faces and gradually started looking longer at the face ultimately chosen up until the decision was made. They proposed the Gaze Cascade model to account for the slightly different pattern of data in the like decision task compared to the other decision tasks. They claimed that people tend to look longer at stimuli they like—a liking effect, which they term "preferential looking"—and tend to like things that they spend more time looking at—the mere exposure effect. Shimojo et al. (2003) claimed that these two component processes work together in a positive feedback loop, influencing the subject's choice in a like decision task. They claimed that the gaze cascade effect occurs only in like decisions and is different from general gaze bias effects that occur in other decision tasks in that it yields a much steeper gaze likelihood curve that does not plateau early, before the decision. However, they made no claims about the cause of the generally observed gaze bias effect.

More recently, Glaholt and Reingold (2009a, 2009b) tested the Gaze Cascade model by preexposing some of the stimuli in an eight-alternative forced choice paradigm (Glaholt & Reingold, 2009a) with two different decision types: Which one the subject liked the most (like) and which one they thought was most unusual (control task). According to the Gaze Cascade model, preexposed items in the like task should be chosen (liked) more often, and should be looked at longer compared to items that were not preexposed in the like task, but the model makes no claims about *nonlike* decision tasks—decisions where the goal is to choose an item based on a criterion other than liking. Glaholt and Reingold's data revealed a robust gaze bias effect, but did not support either of these hypotheses. They found longer looking times on the chosen compared to not-chosen stimuli, but preexposure (i.e., longer previous viewing time) on a given item did not cause that item to be liked over other items. Furthermore, dwell durations on the preexposed stimuli were *shorter* than on the nonpreexposed stimuli, contrary to the prediction of the Gaze Cascade model. According to Glaholt and Reingold, information was obtained previously from the preexposed stimuli and more time was needed to encode and evaluate information about the nonpreexposed items (but see Armel, Beaumel, & Rangel, 2008, for other effects of differing exposure time). Furthermore, Glaholt and Reingold found similar data patterns in the like and nonlike decision conditions, indicating that like decisions might not be qualitatively different from other decisions, and that there might not be a need to consider "gaze cascade" as an effect different from gaze bias. Importantly, using dwell-based analyses (similar analyses used in this paper; see Results section) in addition to gaze likelihood curves they found differences in looking times between the chosen and not-chosen items in the first time the items were viewed, indicating that the gaze bias effect develops more quickly than Shimojo and colleagues suggested. Glaholt and Reingold (2009a) suggested that the *selective encoding* of stimuli—greater processing allocated to decision-relevant features of the stimulus—drives eye movements in visual decision-making tasks in general, and that like tasks might not be different from others.

Given these findings, there is disagreement over the gaze cascade effect. Shimojo et al. (2003) claimed that the gaze cascade effect—an exaggerated gaze bias in like decisions—is qualitatively different from gaze bias in other tasks and is driven by a liking effect that acts in a positive feedback loop with mere exposure. Glaholt and Reingold (2009b), on the other hand, concluded that gaze bias is similar across tasks (including like tasks) and driven by the selective encoding of stimuli.

We suspect that both conclusions are partially correct: Gaze bias, in general, is driven by the selective encoding of stimuli in all decisions. However, when the decision involves liking (i.e., in like and dislike decisions) selective encoding encourages liking to be brought online. Once the liking dimension is activated, liking effects naturally arise. Therefore, in the like task, both selective encoding and liking work simultaneously to boost the size of the gaze bias effect relative to the size of the effect in other tasks, leading to the pattern of data found by Shimojo et al. (2003). Therefore, we would predict that in a dislike decision condition, liking effects would work in the opposite direction of selective encoding and we would expect to see a small or absent gaze bias effect. Specifically, in a dislike task, liking favours the item that will not be chosen, whereas selective encoding favours the item that is more viable on the relevant dimension for selection (i.e., amount of dislike) diminishing the size of gaze bias. This is exactly the pattern of data Shimojo et al. (2003) found, but they dismissed the dislike task as being a task more similar to an objective task. However, a dislike task is semantically opposite to a like task and involves judgement based on the same dimension (liking), so it must be influenced by similar factors as the like task and should not be qualitatively different from like tasks. There are certain problems with the gaze likelihood analysis (discussed in the Results section) that make it difficult to test this prediction. Therefore, in the present study, we employ a dwell-based analysis to explore the effects of liking and selective encoding and interactions between them.

In the present study, we considered the possibility that *both* liking and selective encoding modulate looking in that liking is the dimension used to compare and evaluate the stimuli (i.e., selectively encode) in a like and a dislike task. Conversely, for a task which does not involve liking but involves a decision based on some other criterion—which photograph is older or newer than the other—a different stimulus dimension (e.g., colour content—whether a photograph is black-and-white or colour) will be involved in selective encoding and will influence looking behaviour. The Gaze Cascade model posits that like decisions are qualitatively different from nonlike decisions. However, we suspect that like decisions are not different from other decisions, there is just the additional influence of a liking effect during the decision making process. Therefore, the influence of liking in a like task should be similar to the influence of some other decision criterion in a nonlike task.

We asked subjects to make like/dislike decisions (i.e., "which one of these images do you like more?" and "which one of these images do you like less?") and nonlike decisions (i.e., "which one of these images do you think is older?" and "which one of these images do you think was taken more recently?"). In a like/dislike task the criterion on which items are evaluated is liking, so selective encoding depends on liking and decision type (i.e., whether the goal of the task is to choose the liked or disliked stimulus). In a like task, the chosen (liked) item should be favoured by both a liking effect and selective encoding and there should be a large gaze bias effect. Conversely, in a dislike task, selective encoding should favour the chosen (disliked) item and liking should favour the not-chosen (liked) item, leading to no gaze bias effect because the two competing biases cancel each other out.

In a nonlike decision task, however, liking should no longer influence selective encoding, but rather the influencing factor should be a stimulus dimension that is a useful criterion on which to encode the images. For a recency task, *colour content*—whether the photograph is colour or black-and-white—can be used as a heuristic upon which to make the decision if the two items differ on this dimension. If the items are of different colour contents there should be a large gaze bias effect because the not-chosen item can be quickly rejected based on colour content. Otherwise, if they are both in colour or both black-and-white, colour content is no longer a useful stimulus dimension for selective encoding and there should be no gaze bias effect.

We hypothesized that selective encoding—which involves liking in a like/dislike task and colour content in an older/newer task—should influence looking behaviour (specifically, the gaze bias effect). But at what point in the decision process? Selective encoding implies that we should observe these effects early in the eye movement record, when the items are first encountered, but the precise time course of these effects cannot be determined from previous research. Shimojo et al. (2003) restricted their analysis to data reflecting the *probability* of looking at the chosen versus the not-chosen item during the last 1.6 s of the trial (up until the decision). Glaholt and Reingold (2009a, 2009b) found a gaze bias effect in the first dwell (i.e., the amount of time that item is looked at when first encountered) and the last three dwells of the trial, but they did not include a dislike condition in their study.

In the present study, we compared like, dislike, and nonlike decision conditions and analysed the data specifically to investigate different stages of the decision process. First, we examined the first dwell time on each item, which reflects the encoding stage of the decision process. Because decisions were made very quickly, not much time was spent looking at the images beyond the first dwell. Therefore, the items must have been encoded sufficiently on the first dwell to make such a decision. In fact, on fewer than half the trials were both items fixated more than once (42% of the data). Although, subjects rarely returned to both items they often returned to at least one of the items (80% of the data). We are not arguing that there is no evaluation happening during the first dwell, we are simply stating that due to the fact that the first dwell is the first encounter with the stimulus, the item is being encoded at this time. Second, we examined the remaining time spent looking at each item (i.e., the total time on the item throughout the trial minus the first dwell time), which reflects the postencoding stage of the decision process. As argued by Glaholt and Reingold (2009b), later stages of the trial are more likely to reflect response-related aspects of the decision process (i.e., the tendency to look at an item that one is choosing as one is making a response) rather that more decision-related aspects. If selective encoding modulates the gaze bias effect, then we expected to see differences in the size and direction of the gaze bias effect in early measures of looking behaviour, but not in later, postencoding stages. Specifically, in a like/dislike task decision type should interact with the gaze bias effect in first dwell durations, but there should be no interaction in remaining time. Similarly, in an older/newer task, colour content should interact with the gaze bias effect in first dwell durations but not in remaining time.

METHOD

Subjects

Thirty-two undergraduates from the University of California, San Diego, participated in the experiment. They received credit in exchange for participation and all had normal or corrected-to-normal vision.

Apparatus

Eye movements were recorded via an SR Research Ltd. Eyelink 2 head-mounted eyetracker. Viewing was binocular but only movements of the right eye were recorded. Following calibration, eye position errors were less than 0.5°. Stimuli were presented on a 19 inch (48.26 cm) Viewsonic monitor with a pixel resolution of 1280 × 1024 and subjects were seated 70 cm away from the monitor.

Materials and design

Stimuli consisted of a set of 200 photographs, both colour and black-and-white, obtained from the Internet. The photographs varied in style and subject matter (landscapes, portraits, animals, architecture, etc.), but within a pair the photographs were of the same content (i.e., both portraits, both landscapes, etc.). Photographs were presented in pairs so that subjects made two-alternative forced choice (2 AFC) decisions. Fifty-six per cent of the pairs matched on colour content (i.e., they were both colour or both black-and-white photographs) and 44% of them differed in colour content (i.e., one was colour and the other was black-and-white).[1]

[1] The reason why there is not an equal number of pairs which have the same colour content and different colour content is because we originally planned for the same colour content pairs to be filler items to ensure that the task was not too easy, but later realized that the comparison would be interesting between same colour content pairs and different colour content pairs.

Subjects made one of four decisions for each pair of pictures: "Which one of these pictures do you like more?" (like), "Which of these pictures do you like less" (dislike), "Which one of these images do you think is older?" (older), and "Which one of these images do you think was taken more recently?" (newer). Decision type was a within-subjects manipulation. Each subject made each of the four decisions in blocks of 25 pictures per decision. Each subject saw 100 pairs of pictures in total.

Order of decision and order of blocks of pictures were fully counterbalanced across subjects in a Latin square design. No subject saw any picture more than once, but each picture was seen an equal number of times for each decision type across subjects. Stimulus pairs were presented on a white background with one photograph on the left side of the screen and the other on the right. Each picture was the same width and pictures varied slightly in height.

Procedure

At the beginning of each block the experimenter explained the decision that the subject would be making about the pairs of stimuli within that block. In between blocks the subject rested while the experimenter set up the computer to run the next block. After the experimenter explained the decision, the eyetracker was calibrated and the experiment began. At the beginning of each trial a fixation point was presented in the centre of the screen. Once the subject fixated the point the experimenter pressed a button to make the pictures appear. Subjects were told that they could look at the pictures freely in any order they liked and that once they made a decision they should press a button to make their choice. Button responses were made on a response controller by pressing the right button (to choose the picture on the right) or the left button (to choose the picture on the left). Once a response was made the pictures were replaced by the fixation point.

RESULTS

Trials were excluded if the subject did not fixate one of the items or if there was tracker loss (together this amounted to 1% of the data). Overall, subjects were slightly more likely to choose the first item they viewed, but this probability did not differ across conditions, $p = .53$, .54, .50, and .52 in the like, dislike, older, and newer conditions, respectively. Additionally, there was a tendency to direct the last gaze towards the chosen compared to not-chosen item in all of the four decision conditions, $p = .75$, .64, .69, and .68 in the like, dislike, older, and newer conditions, respectively. When the colour content of the two images was different participants chose the coloured item only half the time in the like decision task ($p = .54$) and the dislike decision task ($p = .44$), but were much more likely to choose the coloured item in the newer decision task ($p = .76$) and much less likely to choose it in the older decision task ($p = .25$).

Effect of decision prompt on eye movements

To examine the effects of decision type, repeated measures analyses of variance (ANOVAs) were run on the data, one for each type of decision comparison: Like/dislike decisions and older/newer decisions.[2] In both of the ANOVAs the two factors were decision type (like vs. dislike or older vs. newer) and choice (chosen vs. not-chosen item).

First dwell duration. First dwell duration was defined as the sum of all fixations on an item (the first time it was viewed) before leaving it. First dwell duration captures the encoding stage of the decision process because it constitutes the first time an item is encountered.

For the like/dislike decisions (see Figure 1a), we found a significant gaze bias effect—subjects spent longer looking at the chosen items ($M = 600$, $SE = 23.42$) than the not-chosen items ($M = 570$, $SE = 24.50$), $F(1, 31) = 8.40$, $p < .01$. There was not a significant effect of decision type—subjects did not spend longer looking at items in the dislike condition ($M = 603$, $SE = 26.57$) than in the like condition ($M = 568$, $SE = 27.08$), $F(1, 31) = 1.77$, $p = .19$,[3] indicating that there was no overall difference in how long it took participants to encode information in the two tasks. Importantly, decision type modulated the gaze bias effect: There was a large gaze bias effect—a liking effect—in the like condition. However, there was no gaze bias effect in the dislike condition, leading to an interaction, $F(1, 31) = 5.36$, $p < .05$. To be clear, although there is a tendency to look longer at the item that will be chosen—a standard gaze bias effect, this effect can be modulated by a completely separate effect—a liking effect. Therefore, there is a large gaze

[2] We ran separate ANOVAs on the like/dislike and older/newer data instead of using liking vs. nonliking decisions as another factor because the distinction between like and dislike is qualitatively different than the distinction between older and newer. Therefore, our design is not really a 2(decision type: Liking vs. nonlike decision) $\times$ 2(attribute: Positive vs. negative) design $\times$ 2(gaze bias effect: Chosen vs. not chosen), but rather a 2(decision type) $\times$ 2(gaze bias effect) design in which one comparison (liking vs. nonliking decisions) has a nested variable within it (like vs. dislike and older vs. newer).

[3] Despite the larger numerical difference between the means for the like and dislike condition compared to the difference between the chosen and not-chosen item, there was much greater variance in the dwell durations between the like and dislike condition, leading to greater error variance in the ANOVA for decision type. Therefore, the main effect of decision type was not significant while the main effect of whether the item was chosen was significant.

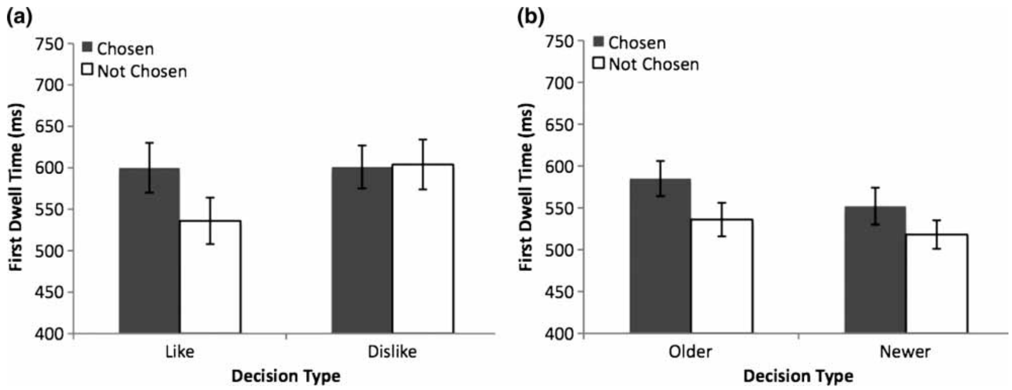

Figure 1. Analyses of the influence of decision type on the gaze bias effect in first dwell time. First dwell times on the chosen and not chosen items in (a) the like and dislike conditions and (b) the older and newer conditions. Error bars represent standard error of the mean.

bias effect—longer looking times on the chosen compared to not-chosen item—in the like condition ($M_{\text{chosen}} = 600$, $SE = 29.25$; $M_{\text{notchosen}} = 536$, $SE = 27.46$), $t(31) = 3.74$, $p = .001$, and no gaze bias effect in the dislike condition ($M_{\text{chosen}} = 601$, $SE = 25.58$; $M_{\text{notchosen}} = 604$, $SE = 30.43$), $t(31) = 0.17$, $p = .87$.

A different pattern of results emerged for the older/newer decisions (see Figure 1b). Although there was a standard gaze bias effect—subjects spent longer looking at the chosen items ($M = 568$, $SE = 18.87$) than the not-chosen items ($M = 527$, $SE = 16.80$), $F(1, 31) = 17.05$, $p < .001$, and there was no significant effect of decision type—subjects did not spend longer looking at items in the older condition ($M = 560$, $SE = 19.07$) than in the newer condition ($M = 535$, $SE = 17.81$), $F(1, 31) = 3.50$, $p = .08$, and there was not the same interaction as in the like/dislike decisions. Importantly, decision type did not modulate the gaze bias effect, resulting in a nonsignificant interaction, $F(1, 31) < 1$. There was no liking effect for the older/newer task; subjects did not have a tendency to look at either older or newer photographs as they did in like/dislike tasks. There was no other tendency operating than the gaze bias effect—the tendency to look longer at the item indicated by the decision type.

Remaining time. Remaining time was defined as the sum of all fixations on an item throughout one trial minus the first dwell time. If an item was not returned to after the first dwell, the remaining time for that item would be 0 ms. It is important to include these zeros in the calculation of remaining time because it is indicative of faster, more complete processing. Therefore, an item that can be encoded and evaluated quickly (i.e., during first dwell) should not need to be refixated and should therefore lead to a remaining time of 0 ms. Remaining time is assumed to reflect the postencoding and decision response process, because the majority of information was already encoded during the first dwell duration.

For like/dislike decisions (see Figure 2a), we found a significant gaze bias effect—subjects spent longer looking at the chosen items ($M = 522$, $SE = 62.33$) than the not-chosen items ($M = 389$, $SE = 55.00$), $F(1, 31) = 55.00$, $p < .001$. There was also a significant effect of decision type—subjects spent longer looking at items in the dislike condition ($M = 541$, $SE = 74.14$) than in the like condition ($M = 370$, $SE = 47.59$), $F(1, 31) = 14.37$, $p = .001$, confirming that the dislike condition was a more difficult task. However, unlike the first dwell results for the like/dislike decision, the gaze bias effect was the same in like and dislike conditions, yielding no interaction, $F < 1$; the liking effect did not influence decision times, only first dwell times (when information was encoded and evaluated).

For the older/newer decisions (see Figure 2b), the same pattern was found. There was a significant gaze bias effect—subjects spent longer looking at the chosen items ($M = 360$, $SE = 36.78$) than the not-chosen items ($M = 298$, $SE = 34.26$), $F(1, 31) = 22.12$, $p < .001$. There was also a significant main effect of decision type—subjects spent longer looking at items in the older condition ($M = 353$, $SE = 37.46$) than in the newer condition ($M = 305$, $SE = 31.12$), $F(1, 31) = 6.10$, $p < .05$, because making a decision about which photograph is older might be a slightly less canonical decision. The gaze bias effect was the same between older and newer conditions, yielding no interaction, $F(1, 31) < 1$; also in remaining time, whether the goal of the task was to find the older or newer item did not influence looking.

Dwell frequency. Eye movement measures of duration can sometimes be inversely related to measures of dwell frequency. To ensure that the pattern

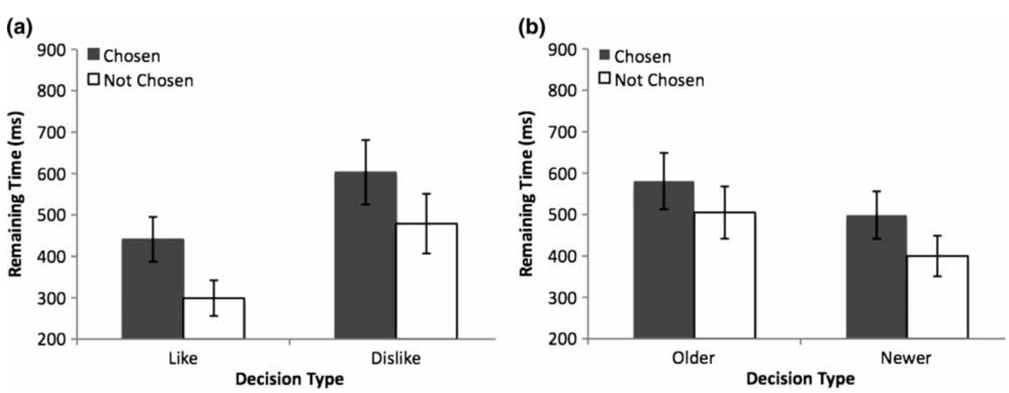

Figure 2. Analyses of the influence of decision type on the gaze bias effect in remaining time. Remaining time on the chosen and not chosen items in (a) the like and dislike conditions and (b) the older and newer conditions. Error bars represent standard error of the mean.

of data obtained above with respect to dwell durations was valid, we also computed the same analyses, using dwell frequency. Dwell frequency was defined as the number of independent times an image was inspected.

The like/dislike results support those obtained with first dwell duration (see Figure 3a); subjects looked more often at the chosen items ($M = 1.88$, $SE = 0.06$) than the not-chosen items ($M = 1.65$, $SE = 0.07$), $F(1, 31) = 118.764$, $p < .001$. There was also a significant effect of decision type—subjects looked more often at items in the dislike condition ($M = 1.85$, $SE = 0.07$) than in the like condition ($M = 1.68$, $SE = 0.06$), $F(1, 31) = 16.22$, $p < .001$, indicating that information was more difficult to encode and evaluate in the dislike task. Importantly, decision type modulated the gaze bias effect: There was a larger gaze bias effect in the like condition than the dislike condition, $F(1, 31) = 6.265$, $p < .05$. The chosen item was looked at more often in both conditions, but in the dislike condition this difference was smaller.

As with first dwell duration, a different pattern of results emerged for the older/newer decisions (see Figure 3b). Subjects looked more often at the chosen items ($M = 1.87$, $SE = 0.06$) than the not-chosen items ($M = 1.68$, $SE = 0.06$), $F(1, 31) = 59.38$, $p < .001$. And there was also a significant effect of decision type—subjects looked more often at items in the older condition ($M = 1.83$, $SE = 0.07$) than in the newer condition ($M = 1.72$, $SE = 0.05$), $F(1, 31) = 9.27$, $p = .005$. Importantly, there was no significant interaction between whether an item was chosen and decision type, $F(1, 31) < 1$. As with first dwell duration, subjects did not have a tendency to look more often at either older or newer photographs as they had a tendency to look at liked items in like/dislike tasks.

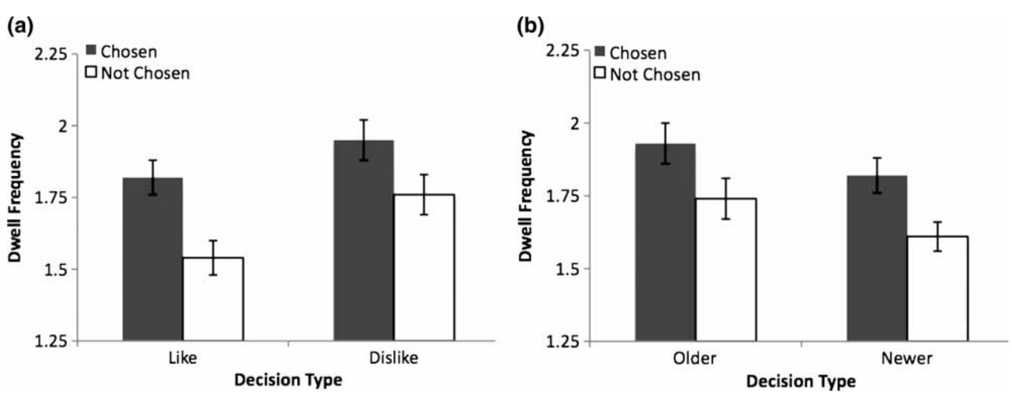

Figure 3. Analyses of the influence of decision type on dwell frequency. Dwell frequency on the chosen and not chosen items in (a) the like and dislike conditions and (b) the older and newer conditions. Error bars represent standard error of the mean.

Effect of colour content on eye movements

To examine the effects of information relevant for selective encoding in the older/newer decision conditions, we ran repeated measures ANOVAs on the data with colour content as a factor. Since there was no influence of decision type on the gaze bias effect in the like/dislike decision comparison we ran a 2(decision type) × 2(chosen vs. not-chosen) × 2(same vs. different colour content) ANOVA on the data. Conversely, because there was no influence of decision type on the gaze bias effect in the older/newer decision comparison we collapsed the data from the older/newer conditions and ran a 2(chosen vs. not-chosen) × 2(same vs. different colour content) ANOVA on that subset of the data. Given that the effects of decision type and the gaze bias effect were already reported earlier, in this section we will only discuss the main effects of colour content, its interaction with decision type and its influence on the gaze bias effect.

First dwell duration. For the like/dislike decisions (see Figure 4a), subjects looked significantly longer at pairs with different colour content ($M = 598$, $SE = 24.97$) than pairs with the same colour content ($M = 571$, $SE = 23.20$), $F(1, 31) = 4.49$, $p < .05$. However, there was no interaction between decision type and colour content, $F(1, 31) = 1.19$, $p = .28$, no influence of colour content on the gaze bias effect, $F(1, 31) < 1$, and no interaction between colour content, decision type, and the gaze bias effect, $F(1, 31) < 1$. In short, colour content did not influence liking judgements in early measures of eye movements.

In contrast, for the older/newer decisions (see Figure 4b), there was a significant main effect of colour content—subjects looked longer at pairs

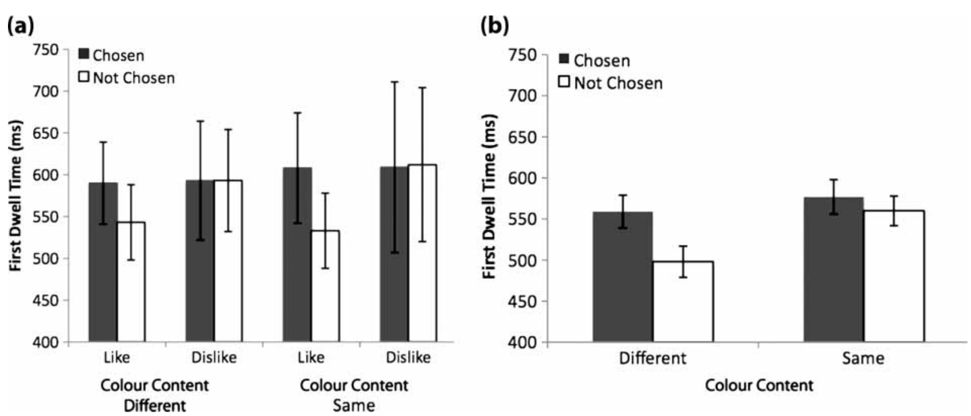

Figure 4. Analyses of the influence of colour content on the gaze bias effect in first dwell times. First dwell times on the chosen and not chosen items in the different colour content and same colour content conditions for (a) the like and dislike decisions and (b) the older and newer conditions, collapsed. Error bars represent standard error of the mean.

with the same colour content ($M = 569$, $SE = 18.34$) than pairs with different colour content ($M = 529$, $SE = 18.27$), $F(1, 31) = 9.28$, $p = .005$, indicating that colour content influenced how easy it was to encode the two pictures to determine the relative time at which they were taken. Furthermore, colour content influenced the gaze bias effect so that there was a significant gaze bias effect in the different colour content condition ($M_{chosen} = 559$, $SE = 20.28$; $M_{notchosen} = 497$, $SE = 18.48$), $t(31) = 4.71$, $p < .001$, but the difference between the chosen and the not-chosen item was not significant in the same colour content condition ($M_{chosen} = 577$, $SE = 21.39$; $M_{notchosen} = 559$, $SE = 18.24$), $t(31) = 1.16$, $p = .26$, yielding a significant interaction, $F(1, 31) = 4.67$, $p < .05$. For a task in which colour content is relevant, this feature can be used to encode and evaluate the items more easily when the two items differ in colour content. When the items are the same colour content, this feature can no longer be used and the gaze bias effect is eliminated, and overall gaze dwells are longer, as well.

Remaining time. For the like/dislike decisions (see Figure 5a), subjects spent longer looking at pairs with the same colour content ($M = 509$, $SE = 69.47$) than pairs with different colour content ($M = 372$, $SE = 48.46$), $F(1, 31) = 10.23$, $p < .005$, presumably because it took longer to confirm a choice when the items were more similar. There was no influence of colour content on the gaze bias effect, $F(1, 31) = 2.45$, $p = .13$. There was a significant interaction between decision type and colour content, showing a bigger effect of colour content in the like condition than the dislike condition, $F(1, 31) = 9.42$, $p < .005$. The three-way interaction between decision type, colour content and the gaze bias effect was not significant, $F < 1$.

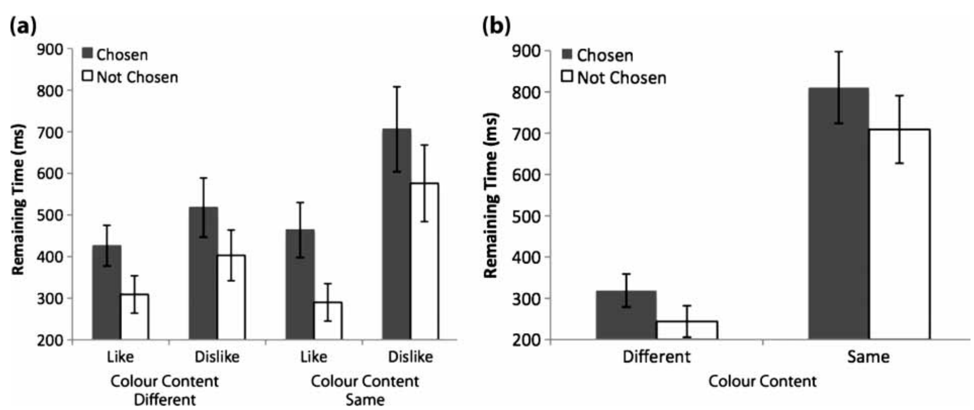

Figure 5. Analyses of the influence of colour content on the gaze bias effect in remaining times. Remaining time on the chosen and not chosen items in the different colour content and same colour content conditions for (a) like and dislike decisions and (b) older and newer conditions, collapsed. Error bars represent standard error of the mean.

For the older/newer decisions (see Figure 5b), there was a significant main effect of colour content—subjects spent longer looking at pairs with the same colour content ($M = 760$, $SE = 83.34$) than ones with different colour content ($M = 281$, $SE = 37.76$), $F(1, 31) = 64.99$, $p < .001$; decisions were more difficult when the two items were more similar. There was no influence of colour content on the gaze bias effect, $F(1, 31) < 1$. Once the colour content information has been encoded and evaluated, it no longer influenced the gaze bias effect in looking behaviour; subjects took longer to encode and evaluate the information in the beginning, but afterwards, the decision process was similar across colour content conditions.

Dwell frequency. For the like/dislike decisions (see Figure 6a), subjects looked more often at pairs with the same colour content ($M = 1.84$, $SE = 0.08$) than pairs with different colour content ($M = 1.71$, $SE = 0.06$), $F(1, 31) = 15.00$, $p = .001$. There was a significant interaction between decision type and colour content, $F(1, 31) = 15.35$, $p < .001$, revealing a bigger difference between dwell frequency in the like and dislike conditions when colour content was different than when it was the same. There was marginally significant interaction between colour content and which item was chosen in dwell frequency, $F(1, 31) = 3.76$, $p = .06$, and no interaction between colour content, decision type, and which item was chosen, $F(1, 31) < 1$. In short, colour content had little influence on liking judgements.

In contrast, for the older/newer decisions (see Figure 6b), there was a significant main effect of colour content—subjects looked more often at pairs with the same colour content ($M = 2.07$, $SE = 0.08$) than pairs with different colour content ($M = 1.54$, $SE = 0.04$), $F(1, 31) = 118.35$, $p < .001$,

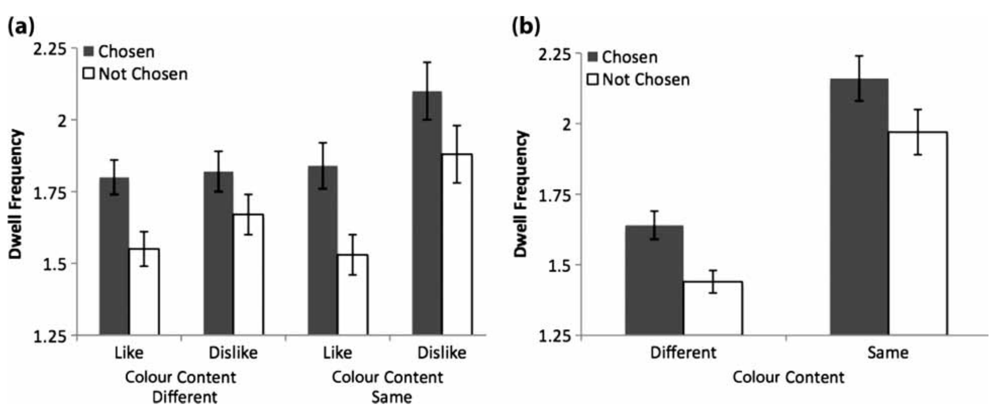

Figure 6. Analyses of the influence of colour content on dwell frequency. Dwell frequency on the chosen and not chosen items in the different colour content and same colour content conditions for (a) like and dislike decisions. And (b) older and newer conditions, collapsed. Error bars represent standard error of the mean.

indicating that colour content influenced how easy it was to encode the two pictures. The interaction between colour content and which item was chosen was not significant, $F(1, 31) < 1$.

Magnitude of the gaze bias effect. Shimojo et al. (2003) proposed that in the like task, gaze cascade (as they term it for that specific task) should be greater than gaze bias in all other tasks. Indeed, this is the pattern we find, but as we argue in the following sections of the paper, the quantitative difference between the like task and other tasks is due to the addition of a liking effect. The results of the analysis can be seen in Figure 7. Figure 7 shows the mean size of the gaze bias effect (as defined by Glaholt and Reingold (2009b); total time on the chosen item minus total time on the not-chosen item) across different decision tasks. We computed a one-way repeated measures ANOVA with decision type. There was no significant difference in the magnitude of the gaze bias effect across decision tasks, $F(2.47, 76.69) = 2.62$, $p = .07$.[4] The gaze bias effect, although not significantly different is greatest in the preference task, but, as argued before, this can be attributed to the addition of the liking effect.

Gaze likelihood analyses. Given the centrality of gaze likelihood analyses to the claims made by Shimojo et al. (2003) we computed gaze likelihood curves on our own data. Gaze likelihood curves consist of plotting the probability of looking at the chosen item over the last 1.6 s of the trial up until response. Trials were not included if a response was made before 1.6 s.

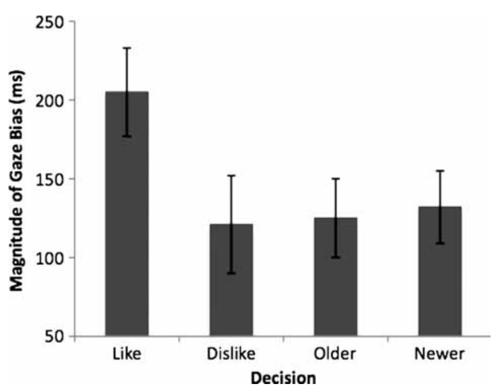

Figure 7. Analysis of the magnitude of the gaze bias effect (total time on chosen item – total time on not-chosen item) across decision tasks. Error bars represent standard error of the mean.

[4] We used the corrected *F*-values because there was a slight violation of sphericity.

As can be seen in Figure 8, there are no qualitative differences in the pattern of results across decision conditions. This result, of course, differs from those reported by Shimojo et al. (2003). The only difference in our data between decision conditions is quantitative. Essentially, the gaze likelihood curves rise most steeply in the like condition and least steeply in the dislike condition. These differences support the results we find with our dwell-based analyses and can be explained by the additional influence of a liking effect boosting looking on the chosen item in the like condition and boosting the not-chosen item in the dislike condition. There does not seem to be a need to posit a different effect (i.e., the gaze cascade effect) for like decisions. The general gaze bias effect is operating in all decision conditions, and a liking

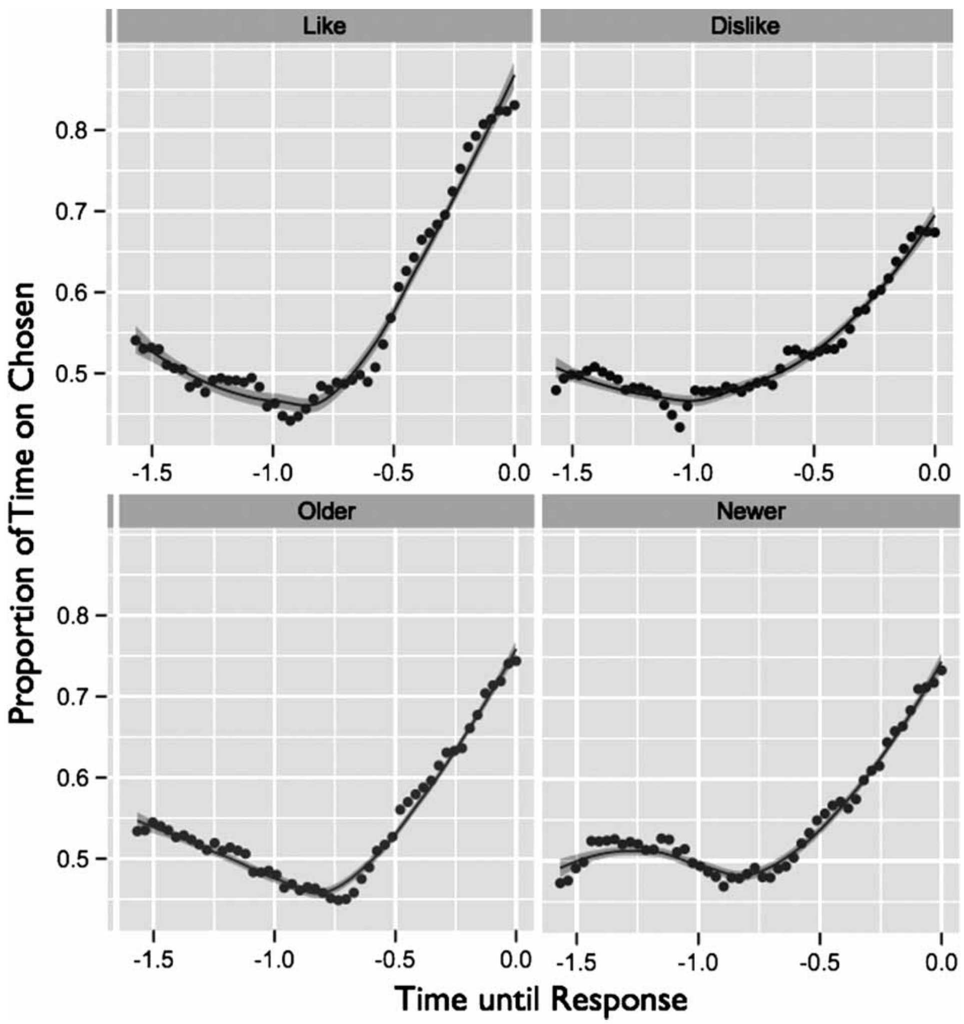

Figure 8. Gaze likelihood analyses, which plot the probability of fixating the chosen item in bins of 32 ms for the last 1.6 s up until response. Separate plots represents the four different decision conditions: Like, dislike, older, and newer.

effect is also operating in decisions based on liking (i.e., like and dislike decisions).

We do not report gaze likelihood curves for the data separately by colour content because comparing the two conditions is not appropriate using such an analysis. An analysis of this type aggregates data over a certain time period (the last 1.6 s), but there is no reason to believe that the cognitive processes involved in the last 1.6 s of one trial corresponds to the same process as the last 1.6 s of another. That is, if the decision is made quickly in one trial (say, in 1.6 s) then the analysis encompasses the entire decision. However, if the decision takes much longer (say, 5 s), the gaze likelihood analysis only includes the end part of it. Therefore, the gaze likelihood analysis incorporates many different processes across many different types of trials. Furthermore, it defines the grain of analysis somewhat arbitrarily (choosing a specific time window) instead of letting the analysis be driven by the behaviour (by breaking it down according to how long a person spends looking at a given stimulus and when they decide to do so). This aspect of the analysis is particularly complicated for the comparison between same and different colour content conditions because same colour content conditions are much longer than different colour content conditions. Therefore, the gaze likelihood analysis includes only the end part of the slow (same colour content) trials and the majority of the fast (different colour content) trials. Furthermore, only trials for which the decision was made at or after 1.6 s were included. For fast decisions, such as ones where colour content can be used as a heuristic, more trials will be excluded from the analysis than for slow decisions.

DISCUSSION

Our data indicate that, as predicted, selective encoding drives the gaze bias effect and, under certain conditions, liking effects can boost or eliminate it. Indeed, our results suggest that people tend to look longer at a photograph that they like when their decision is based on liking an item—a liking effect. When their task is to select the liked item, selective encoding works with the liking effect and there is a large gaze bias effect. However, when the goal is to choose the disliked item, the gaze bias effect is attenuated by the tendency to look at the liked item— the liking effect competes with selective encoding. This interaction did not exist when liking was not relevant to the decision (i.e., during a nonlike (older/newer) decision).

Shimojo et al. (2003) claimed that preferential looking (a liking effect) is involved in looking behaviour in a liking-based decision task. Indeed, our data support this finding. However, contrary to the Gaze Cascade model, we find that the liking effect and gaze bias (selective encoding) do not interact in a positive feedback loop, but are rather separate and additive effects. A positive feedback loop would indicate that gaze bias would become amplified as the trial progressed, but we find no interaction in remaining time on the trial between the gaze bias effect and decision type (like vs. dislike). The basis of the Gaze Cascade model (and the need for the gaze cascade effect) is the gaze likelihood analysis. Indeed, we do find a steeper curve in the like condition than in other conditions, but as we and Glaholt and Reingold (2009b) have argued, this analysis obscures effects that are real and emphasizes effects that may be artifacts of the way the analysis is conducted. Gaze likelihood curves provide a visual representation of the probability of looking at the chosen item during response, but are not very informative above and beyond that.

Furthermore, our results also suggest that although liking does not influence the gaze bias effect in a nonlike (older/newer) task, colour content—which is a useful stimulus feature to selectively encode—does. That is, if someone is trying to make a decision about which of two photographs was taken more recently they would, when possible, encode the items based on colour content (whether the photograph is black-and-white or colour) as a heuristic to make their decision. When the two photographs share colour content, that visual feature is no longer informative, and the decision must be based on other features of the image that might be more difficult to encode. Therefore, when colour content was a useful cue, information was easier to encode (dwell durations were shorter) and there was an amplified gaze bias effect (subjects spent comparatively little time looking at the not-chosen item). Since colour content is not a useful heuristic for a liking task, it did not influence the gaze bias effect in the like or dislike conditions. The similarity between the effect of liking in like and dislike tasks and the effect of colour content in the older and newer tasks shows that gaze bias is not qualitatively different between the preference (like/dislike) and nonlike (older/newer) decisions. Therefore, there is no need to posit a different effect (gaze cascade) for liking decisions. Any difference from other conditions is due to the additive effect of liking. Indeed, when we analysed our data using the gaze likelihood analysis we did not find the qualitative difference that Shimojo et al. (2003) found, but rather we found similar results to Glaholt and Reingold (2009a, 2009b); mainly, gaze bias is a general effect that is qualitatively consistent across tasks. This influence on the gaze bias effect (modulated by liking or colour content) was present in early measures of the decision process—when encoding takes place. In remaining time, there was a standard gaze bias effect across all conditions, regardless of liking or colour content.

Although there is a large literature on decision-making (see Koehler & Harvey, 2004), most studies investigate what affects the choices people ultimately make to extrapolate the process at which they arrived at the choice. In the present study we used online measures of the decision-making process to *observe* how it develops over time. But *how* and *when* do different phrasings that prompt a decision affect the decision process? We believe that our methodology and method of analysis will be useful in investigating the underlying processes (and timing thereof) of other decision-making phenomena.

Our data indicate that, in our task, differences in behaviour arise because people encode information differently (depending on the decision criterion) in different conditions because these effects show up in early eye movement measures. It is not surprising that early measures of eye movements during decision-making tasks (i.e., those that reflect the encoding stage) would be sensitive to liking and decision type in a like/dislike task or colour content in an older/newer task. In order to make a decision one must first encode information; that information must be encoded and evaluated in a way that is relevant to or useful for the decision. The consistency of the gaze bias effect (i.e., no interactions with decision phrasing or colour content) in remaining time may reflect the fact that people tend to look at the item they select while making their response more than it reflects other aspects of the decision process (see also Glaholt and Reingold, 2009b). In our task, subjects were required to press a button to indicate their response and end the trial. As reported before, subjects were more likely than chance to be looking at the item they chose when they were making their response.

In summary, people tend to look longer at the item they will choose than the item they will reject—a gaze bias effect. At the same time, people tend to look longer at an item they like than an item they do not like—a liking effect. If these two tendencies are pitted against each other by asking someone to select the item they like the least, it will be reflected in the eye movement record in that people will look equally at the two items. Furthermore the gaze bias effect arises because people form judgements about items as they are performing the task online. This selective encoding can change depending on the goal of the task (i.e., whether the task is to choose the liked or disliked item) and how easily the stimuli can be encoded for the task (i.e., whether the items are similar or dissimilar on a dimension such as colour content). There is no need to posit a different effect for like decisions and other decisions. The difference in the size and pattern of effects seen in the like condition were not due to Gaze Cascade, but rather to the additive effects of a standard gaze bias—selective encoding—and the tendency to look at a preferred item—a liking effect. Our study replicates some of the past findings of Shimojo et al. (2003) and Glaholt and Reingold (2009a, 2009b), but lends new insight into the nature of the gaze bias effect by contrasting like and dislike conditions using dwell duration and dwell frequency analyses to tease apart the different effects of selective encoding and liking, which thus far have been obscured by the gaze likelihood analysis.

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