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Effects of salience are both short- and long-lived

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ABSTRACT

A salient object can attract attention irrespective of its relevance to current goals. However, this bottom up effect tends to be short-lived (e.g. <150 ms) and it is generally assumed that top down processes such as goals or task instructions operating in later time windows override the effect of salience operating in early time windows. While the majority of studies on visual search and scene viewing comply with the assumptions of top down and bottom up processes operating in different time windows and that the former overrides the latter, we point to some possible anomalies in decision research. To explore these anomalies and thereby test the two key assumptions, we manipulate the salience and valence of one information cue in a decision task. Our analyses reveal that in decision tasks top down and bottom up processes do not operate in different time windows as predicted, nor does the former process necessarily override the latter. Instead, we find that the maximum effect of salience on the likelihood of making a saccade to the target cue is delayed until about 20 saccades after stimulus onset and that the effects of salience and valence are additive rather than multiplicative. Further, we find that in the positive and neutral valence conditions, salience continues to exert pressure on saccadic latency, i.e. the interval between saccades to the target with high salience targets being fixated faster than low salience targets. Our findings challenge the assumption that top down and bottom up processes operate in different time windows and the assumption that top down processes necessarily override bottom up processes.

Most contemporary theories of visual attention agree that attention is influenced by top down and bottom up processes, such as the relevance of an object to the current goal and the salience of an object relative to its surroundings (Corbetta & Shulman, 2002). However, what contemporary theories do not agree about is the extent to which bottom up control influences attention. At one extreme, some authors have argued that in everyday tasks bottom up control, exemplified by for instance salience, plays little or no role in the control of eye movements (Tatler, Hayhoe, Land, & Ballard, 2011). At the other extreme is a class of models predicting continuous influence of salience on eye movement control (Borji & Itti, 2013; Itti & Koch, 2001). Between the two extremes is a third view which assumes that in some way bottom up control depends on the extent of top down control. One view, for instance, assumes that bottom up control of attention is operative in a short time window immediately after the onset of a visual scene (Donk & van Zoest, 2008; Theeuwes, 2010; Van Zoest, Donk, & Theeuwes, 2004), the main idea being that top down control requires more time while bottom up features such as salience are processed faster (de Vries, Hooge, Wiering, & Verstraten, 2011). Immediately after or perhaps overlapping this early time window, top down control becomes operative and overrides bottom up control (Goschy, Koch, Müller, & Zehetleitner, 2013). We here refer to this intermediate position as the *timing account* as proposed by Van Zoest, Donk and Theeuwes (see also Foulsham & Underwood, 2007; Tatler, Baddeley, & Gilchrist, 2005; Theeuwes, 2010).

The timing account is more flexible than the two extreme views on bottom up control and perhaps may consequently account for a wide range of observations. For instance, several studies have demonstrated a fast decaying effect of salience as a function of saccadic latency, i.e. the time from stimulus onset to a saccade is made to the target, with short-latency saccades being primarily salience driven and long-latency saccades being primarily top down driven (Donk & van Zoest, 2008; Goschy et al., 2013; Van Zoest & Donk, 2006; Van Zoest et al., 2004). Although these studies suggest that the effect of salience dissipate after the first saccade, a second group of studies in which eye movements have been measured over a longer time window suggest a slower decay in the effect of salience (Foulsham & Underwood, 2007; Fuchs, Ansorge, Redies, & Leder, 2011; Helo, Pannasch, Sirri, & Raemae, 2014; Parkhurst, Law, & Niebur, 2002; Tatler et al., 2005). These studies are not necessarily at odds with the timing account seeing that the effect of salience typically wanes within the first 10–20 fixations to the scene. In the absence of top down control, presumably in free viewing or memory encoding tasks, salience may influence eye

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movements beyond the first 20 saccades (Foulsham & Underwood, 2007; Tatler et al., 2005) while tasks where top down control is presumably strong, bottom up control is completely overridden (Einhäuser, Rutishauser, & Koch, 2008).

Overall, these findings seem to fit with the timing account and the general assumption that bottom up control influences eye movements as long as no top down control is operational, e.g. early after stimulus onset or in free viewing or memory encoding tasks. However, there is a last group of studies that do not quite fit the picture. These studies have shown that salience influences eye movements in decision tasks and that these changes furthermore influence the eventual choice (Bialkova & van Trijp, 2011; Lohse, 1997; Milosavljevic, Navalpakkam, Koch, & Rangel, 2012; Navalpakkam, Kumar, Li, & Sivakumar, 2012; Orquin, Bagger, & Mueller Loose, 2013; Towal, Mormann, & Koch, 2013). The challenge for the timing account is that almost all decision theories assume that eye movements in decision-making are entirely under top down control (Orquin & Mueller Loose, 2013). While many decision theories may be wrong in their strong assumption, there is little doubt that decision tasks are heavily influenced by top down control. For instance, more than 40 studies show that decision-makers are more likely to fixate information that has a high utility or validity, i.e. information that is important to the task (Orquin & Mueller Loose, 2013). According to the timing account and the assumption that top down control cognitively overrides bottom up control, salience effects should therefore have no room in decision-making. Looking closer at these studies does in fact suggest some concessions to the timing account. Milosavljevic et al. (2012), for instance, found that salience mainly predicts fixations and choice under short exposure times (<200 ms) and when preferences are weak, i.e. presumably exerting less top down control. Orquin et al. (2013) found that over the course of multiple decision trials, the effect of individual preferences on eye movements increases while the effect of bottom up processes such as size and salience decreases. However, most of the decision studies do not employ any time constraints, nor do they analyze the temporal profile of salience; to accommodate their findings of the timing account, we would have to assume that the effect of salience is operative only in an early time window after stimulus onset. A short-lived effect of salience on the other hand seems inconsistent with the findings that salience influences choice.

A different interpretation of these studies suggests that, at least for decision tasks, top down control does not necessarily override bottom up control. If, for instance, salience is correlated with the utility or validity of information, it could potentially enhance the decision outcome by increasing attention to high-utility choice options and decreasing attention to low-utility options. In such a situation salience would effectively serve as a heuristic (Gigerenzer & Goldstein, 1996) reaching better decisions with less effort. From a cognitive process perspective, it has been suggested that top down and bottom up processes may compete in parallel so that over time the most suitable process is chosen (Nyamsuren & Taatgen, 2013). Given a correlation between salience and utility, e.g. a foraging monkey prefers ripe fruit because of its superior calorie density, but ripe fruit also has a different color than the surrounding foliage (Hiramatsu et al., 2008), these models would predict an increasing reliance on salience over time (Anderson, Laurent, & Yantis, 2011).

Considering these theories and the findings that salient cues influence both eye movements and decision outcomes, it seems that there is some reason to expect a longer lasting effect of salience in decision tasks. However, none of the previous studies allow us to verify this hypothesis and the question therefore remains: Does top down control override bottom up control in decision tasks, and, if so, in what time window? The timing account proposes that top down control should either completely override bottom up control except for the first or second saccade (fast decay) or that bottom up control may wane over the course of the first 10–20 fixations (slow decay).

Whether or not this prediction holds has implications for our understanding of top down and bottom up control and to test this assumption we conducted a study on top down and bottom up control of eye movements in decision-making. As an operationalization of top down and bottom up control, we manipulated the *valence* and *salience* of one product feature, i.e. a product label, in a consumer choice task for different food products. Salience was manipulated by changing the color and contrast of the label while valence was manipulated by providing participants with positive, negative, or neutral (control) information about the meaning of the label. As dependent variables we analyzed the likelihood of saccadic selection and the latency of saccades to the manipulated label for each position in the absolute and relative saccade order.[1] For the absolute saccade order, i.e. the ordinal saccade number for any object in the task, the timing account predicts a waning effect of salience within the first 10–20 saccades with a maximal effect of salience immediately after stimulus onset. Furthermore, given stronger top down control in the positive and negative valence conditions relative to the control condition, the timing account also predicts an attenuated or even lacking effect of salience in the positive and negative conditions. For the relative saccade order, i.e. the ordinal saccade number for saccades to the label, the timing account predicts a complete overriding of salience effects after the first saccade to the label as the participant now possesses information about the object, which will allow top down control (Henderson, Weeks, & Hollingworth, 1999).

1. Methods

1.1. Participants

A large sample consisting of 150 participants was recruited through a consumer panel provider to represent a broad sample of the Danish population. Two participants were excluded after the experiment due to insufficient data quality resulting in a total sample of 148 participants. The sample size was decided by allocating 25 participants to each cell in the experiment thereby exceeding a suggested threshold of minimum 20 observations per cell (Simmons, Nelson, & Simonsohn, 2011). The participant age range was 30–65 years ($M = 46.32$) with an approximately even distribution of male and female participants (77 women). Only participants who had normal or corrected to normal vision were included in the study. Each participant received approximately €20 for completing the experiment.

1.2. Stimuli and apparatus

The experimental stimuli consisted of eight choice sets, each with two alternatives presented on the left and the right side of the screen. The alternatives were high resolution images of existing consumer products matched on preference rank in a pilot study. The manipulated product feature, a biotechnology label, was assigned to one alternative in each choice set and the salience of the label was manipulated by controlling the contrast. Eye movements were recorded using a table-mounted eye tracker (Tobii T60 XL) with a temporal resolution of 60 Hz and a screen resolution of 1920 × 1200 pixels. The screen subtended a visual angle of 46.5° horizontally and 30.1° vertically. At the average viewing distance of 60 cm from the screen, binocular accuracy is .5° and precision .18°. Fixations were computed using the velocity based I-VT algorithm (Salvucci & Goldberg, 2000). For each choice set an area of interest (AOI) was drawn around the biotechnology label. To

[1] Readers who are more familiar with analyzing eye movements in terms of fixations may think of our dependent variables as the likelihood of fixating the label and the latency of that fixation, i.e. the time from stimulus onset until the beginning of the fixation. We prefer the terms saccadic selection and saccadic likelihood to maintain consistency with previous literature on this subject.

account for inaccuracy in recording of fixation locations, the margins of the AOIs were approximately .5° larger than the label. For different views on optimal AOI sizes see Holmqvist et al. (2011) and Orquin, Ashby, and Clarke (2015).

Eye trackers frequently fail to obtain valid measures of the eye position due to blinks and artifacts such as participants moving outside the tracking range of the remote eye tracker. In an analysis of fixation likelihood, missing data essentially counts as an absence of fixations to the target and it follows that data must be missing at random for the analysis to provide an unbiased estimate. To meet this requirement we dropped two participants from the analysis due to a high degree of missing data (0 and 11.3% valid samples respectively). The remaining 148 participants had an average sampling rate of 92.3% ranging between 79.5% and 99.7%. To test the assumption of data missing at random, we regressed the percentage missing data per trial on the bottom up and top down conditions. Neither the bottom up, $p = .98$, or the top down condition, $p = .23$, were significant suggesting that data was missing at random.

1.3. Design and procedure

We conducted a two-alternative forced choice experiment with a 3×2 mixed within-between subjects factorial design manipulating the valence (*approach*, *avoidance*, *control*) and salience (*high salience vs low salience*) of a biotechnology label. The effect of the valence manipulation was first tested in an online pilot study using a convenience sample ($N = 200$) and different product categories. To increase the robustness of the study we used eight replications for each cell in the design. To minimize demand characteristics we included isolated control blocks without the biotechnology label resulting in 24 choice sets of which 16 were critical trials. To avoid multiple exposures to the same choice set, e.g. first choosing a product with the biotechnology label and later without it, participants were blocked according to the high salience, low salience and no label condition.

The study was conducted in a light-controlled laboratory environment and participants were randomly assigned to treatment blocks. Participants were informed that the study was a consumer test of food products and read instructions on the screen at their own pace. Participants in the *approach* condition additionally received positive information about the manipulated product feature. Specifically, they were informed that the label was an EU initiative in order to enhance consumption of sustainable foods produced by means of biotechnology. Participants in the *avoidance* condition received additional negative information and were informed that the label was an EU initiative allowing consumers to easier identify and avoid genetically modified foods. Participants in the control condition did not receive any information about the meaning of the label. The eye tracker was calibrated using the Tobii Studio calibration procedure. During the experiment participants first saw a fixation cross for 500 ms followed by a choice set. Participants indicated their preferred product with a key press and used as much time as needed to make their decision.

2. Results

2.1. Descriptive statistics

Participants made on average 5.2 fixations to the label and made their decision after an average of 67 fixations and 7.6 s. The label was fixated in 61.3% of the trials. An example of a typical scanpath is shown in Fig. 1. As a test of the valence manipulation, we computed the means and confidence intervals for each valence condition. The CIs were calculated as $+/- 1.96 \times SE$. The manipulation of valence was considered successful. The likelihood of choosing the target product in the no label condition, $M = .48$, CI_{95} [.44, .52], and the control condition, $M = .49$, CI_{95} [.44, .54], did not differ from chance level nor from each other. In other words, a product carrying a label about which participants received no information was equally likely to be chosen as the same product without the label. Participants in the approach condition, $M = .59$, CI_{95} [.54, .64], were roughly 20% more likely to choose the target product compared to the control condition and participants in the avoidance condition, $M = .34$, CI_{95} [.29, .39], were roughly 44% less likely to choose the target product.

The first analysis concerns the temporal profile of salience on driving saccades to the label. According to the timing account, we should expect a waning effect of salience over time with a maximum effect at stimulus onset and the lowest or even no effect after 10–20 saccades. Furthermore, the effect of salience should be stronger for the control condition compared to the negative and positive valence conditions where the effect should approximate zero. To test these assumptions we estimated the likelihood of making a saccade to the label as a function of salience, absolute saccade order, and valence in a full factorial design. Saccade

Fig. 1. Example of a choice set with scanpath overlay from one participant. The labeled target product is to the right. Circles represent fixations.

Table 1
Effects of salience, valence and absolute saccade order on the likelihood of saccadic selection. Bold values indicate significance at p>.05.

Effect	Numerator *df*	Denominator *df*	*F*	*p*
Valence	2	77,877	6.47	**.0015**
Salience	1	77,877	18.41	<**.0001**
Valence * salience	2	77,877	3.31	**.0366**
Saccade order	1	143	22.31	<**.0001**
Saccade order * valence	2	77,877	5.03	**.0065**
Saccade order * salience	1	77,877	3.16	.0755
Saccade order * valence * salience	2	77,877	1.6	.2009

order was treated as a linear metric variable which assumes a linear monotonic effect of saccade order on saccadic selection. It should be noted that this assumption may be an oversimplification. The saccadic likelihood had a binomial response distribution and a logit link function constraining the predicted values between zero and one. The best fitting model was selected using a step-up approach (see Appendix A). The results are presented in Table 1 (for coefficients see Appendix B).

The best fitting model suggests that all terms, except for the interaction terms between top down and bottom up control, influence the likelihood of making a saccade to the label with high-salience labels being significantly more likely to attract saccades than low-salience labels. This suggests that the effect of salience is invariant across levels of top down control. In order to examine the temporal profile of salience on saccade likelihood, we plotted the likelihood of making a saccade to the label as a function of saccade order and salience (see Fig. 2). To aid the interpretation we also computed an intensity map indicating the significance level based on the χ^2 test. The plot suggests that the effect of salience does not wane over time with a maximum effect at stimulus onset and the lowest effect after 10–20 saccades. Rather, it seems that the largest effect of salience occurs in a window between 20 and 35 saccades after stimulus onset (cf. Fig. 3 in Foulsham & Underwood, 2007).

2.2. Likelihood and latency of saccades in the relative saccade order

In the first analysis we demonstrated a delayed effect of salience in the absolute saccade order roughly occurring between saccade numbers 20 and 35. In the second and third analyses we estimated the likelihood and latency of saccades to the label as a function of the relative saccade order, i.e. the ordinal number of saccades to the label. Analyzing the relative saccade order allows us to estimate the effect of salience for the first saccade to the label compared to subsequent saccades to the label. The timing account predicts that the effects of salience are limited to the first saccade to the label. To estimate the influence of top down and bottom up modulation on saccadic latency, we organized the latencies in a longitudinal structure in which the first row represents the latency from stimulus onset to the first fixation on the label, the second row the latency from the termination of the first fixation to the beginning of the second fixation and so forth. Additionally each saccade to the label can be thought of as occurring with a certain probability. The probability is a function of the salience and the relevance of the label to the decision-maker and conditional on whether a previous saccade had been made to the label. To estimate the conditional likelihood of a participant making a saccade to the label, we created a longitudinal dataset in which each saccade was represented by 1 and the absence of a saccade by 0. If a participant made, for instance, three saccades to the label, the dataset would contain three rows of ones followed by a row of zeros to estimate the conditional probability of making a fourth saccade to the label. The saccadic latency and saccadic likelihood models were estimated by means of generalized linear mixed models (SAS PROC GLIMMIX) with saccade order, label valence, and label salience as fixed effects in a full factorial design. The saccadic likelihood had a binomial response distribution and a logit link function constraining the predicted values between zero and one. The best fitting models were selected using a step-up approach (see Appendix A). The results are presented in Table 2 (for coefficients see Appendix C and D).

To further explore the role of top down and bottom up processes at different positions in the relative saccade order, we analyzed the effects of valence and salience on saccadic latency and saccade likelihood separately for the first saccade to the target and for subsequent saccades. According to the timing account we would expect a significant effect of salience on saccade likelihood and saccadic latency for the first saccade to the label while all subsequent saccades and saccadic latencies would be driven by the valence of the label. As predicted by the salience model and the timing account, we found a significant effect of salience on saccade likelihood for the first saccade to the label, $F(1, 1027) = 7.59$, $p = .006$, and no effect of salience on subsequent saccades to the label, $F(1, 6172) = 0.47$, $p = .495$. However, contrary to the predictions of the two models we found no effect of salience on the latency of the first saccade, $F(1, 554) = 1.57$, $p = .211$, but a significant effect on the latency of subsequent saccades, $F(1, 5333) = 9.54$, $p = .002$. Planned contrasts showed that high salience labels reduced saccadic latencies by an average of 250.72 ms in the approach condition, $p = .006$, and 268.25 ms in the control condition, $p = .003$. There was no effect of salience on saccadic latencies in the avoidance condition, $p = .338$.

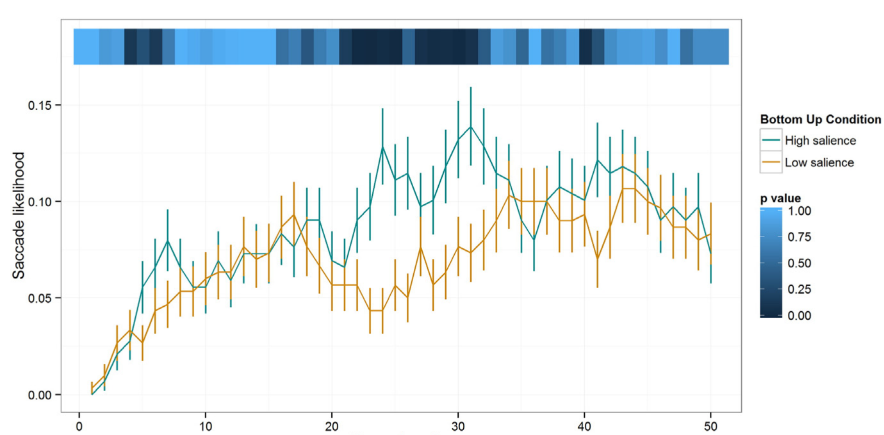

Fig 2. Likelihood of making a saccade to the label as a function of the absolute saccade order and salience for the first 50 saccades. Plot only contains participants with more than 50 saccades. The intensity map indicates the significance level for the high vs low salience conditions through the saccade order. Error bars represent standard errors of the means.

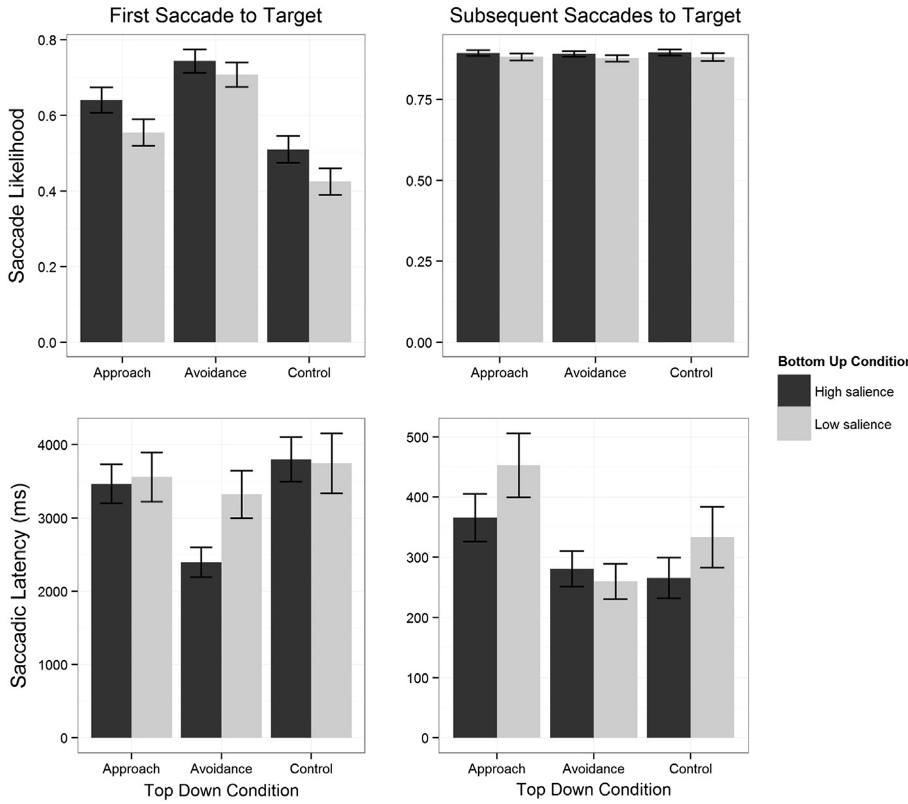

Fig 3. Effects of salience on saccadic selection (top row) and saccadic latency (bottom row) under approach, avoidance, and control conditions for the first and subsequent saccades to the target. Error bars represent standard errors of the means.

3. Discussion

While most vision researchers agree that both top down and bottom up processes each can contribute to eye movement control, it has been notoriously difficult to demonstrate if and when these processes jointly influence eye movements. A prominent view suggests that these processes operate in separate time windows (Donk & van Zoest, 2008; Theeuwes, 2010; Van Zoest et al., 2004) and that later top down processes override earlier bottom up processes (Einhäuser et al., 2008; Foulsham & Underwood, 2007; Tatler et al., 2011). This timing account seems to fit well with the vast majority of studies investigating salience as an instance of bottom up control. Most of these studies fall into one of four categories: a) studies showing no effect of salience, typically in real world tasks where top down control is presumably high; b) studies showing a fast decay of salience with effects limited to the first 100–200 ms after stimulus onset; c) studies showing a slow decay of salience with effects waning over the first 10–20 saccades after stimulus onset; d) studies showing a longer lasting effect of salience in tasks where top down control is presumably low or absent, such as free viewing or memory encoding. Overall these studies suggest that salience may influence eye movements but only in a limited time window or when top down control is absent. When top down control becomes operative, it overrides salience. However, almost all of these studies are based on visual search or scene viewing tasks and we propose that a different group of studies related to decision-making may shed new light on the topic. Particularly, these studies seem to suggest a larger influence of salience on eye movements and behavior than what would otherwise be expected in a task with strong top down control. To investigate this apparent paradox we conducted a choice experiment manipulating the *salience* (high vs low salience) and *valence* (positive, negative and neutral control condition) of one information cue in an orthogonal design allowing us to disentangle top down and bottom up processes over time.

Our results suggest first of all that the effect of salience on the likelihood of making a saccade to the target does not wane over time with a maximum effect immediately after stimulus onset. Rather it seems that salience does not influence saccadic likelihood until after 20 saccades from stimulus onset and mainly in a window from saccade numbers 20 to 35. Furthermore, the effect of salience is invariant to top down control. A more detailed analysis of saccades to the target revealed additive effects of salience and valence on the likelihood of the first saccade to the target, but no effect of either factor on subsequent saccades. Analyzing the latency of

Table 2
Effects of salience, valence and saccade order on the conditional likelihood of saccadic selection and saccadic latency. Bold values indicate significance at p>.05.

Effect	Numerator *df*	Denominator *df*	*F*	*p*
Saccade likelihood				
Valence	2	7357	7.27	**.001**
Salience	1	7357	5.01	**.025**
Valence ∗ salience	2	7357	1.97	.139
Saccade order	1	7357	0.72	.395
Saccade order ∗ valence	2	7357	3.17	**.042**
Saccade order ∗ salience	1	7357	0.12	.730
Saccade order ∗ valence ∗ salience	2	7357	1.36	.256
Saccadic latency				
Valence	2	6036	9.82	<**.0001**
Salience	1	6036	19.31	<**.0001**
Valence ∗ salience	2	6036	0.67	.512
Saccade order	1	135	97.27	<**.0001**
Saccade order ∗ valence	2	6036	3.69	**.025**
Saccade order ∗ salience	1	6036	27.52	<**.0001**
Saccade order ∗ valence ∗ salience	2	6036	1.38	.251

saccades from stimulus onset, we found no effect of salience on the latency of the first saccade but a continuous effect of salience on the latency of subsequent saccades with high salience targets being fixated faster than low salience targets. This effect was not invariant to top down control and was present only in the positive valence and control condition.

Overall, our results are difficult to accommodate with the timing account and the idea that top down processes must override bottom up processes. Particularly the finding that the effects of salience on saccade likelihood seem to peak only after 20 saccades from stimulus onset challenges the assumption that top down and bottom up processes operate in different time windows. Furthermore, the finding that salience may contribute to saccadic latency after the first saccade to the target seems directly contradictory to what we should expect. However, it is clear that top down can override bottom up processes in this task, which at least confirms the assumption of hierarchical control. The main issue therefore seems to be if top down processes can override bottom up processes then when and why do they do so? Two lines of thought may contribute to explain this. First, it has been proposed that top down control changes the weights in the salience map (Navalpakkam & Itti, 2005) which could account for the prolonged effect of salience on saccadic latency for subsequent saccades as well as the additive effects of salience and valence on saccadic likelihood. On the other hand, this view does not fit well with the finding that the effect of salience only peaks after 20 saccades. A second view has been offered by Tatler et al. (2005) who propose that the salience map is invariant while the top down processes may diverge over time. This view could potentially explain the delayed effect of salience on saccadic likelihood as a consequence of decision-makers employing a decision strategy that varies in its sensitivity to bottom up influences. One might, for instance, imagine that decision strategies that favor exploration over exploitation would benefit from openness to bottom up processes particularly in environments where salience is correlated with utility or validity (Anderson et al., 2011; Frey et al., 2011). Strategies favoring exploitation would on the other hand benefit from strong top down control thereby minimizing distractions due to bottom up influences. It is, furthermore, plausible that decision-makers would cycle between exploration and exploitation in a single decision trial (Hertwig & Erev, 2009) which could lead to cycles of increasing and decreasing bottom up control.

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Appendix A

Model fit measures for analyses 1 to 3.

Randomeffectsspecification	Analysis 1 AIC	Analysis 2 AIC	Analysis 3 AIC
Fixed effects only	43,403.75	6319.86	112,962.0
Ran intercept by participant	41,739.71	5987.26	112,948.9
Ran intercept by participant/choice set	40,779.78	**5874.99**	112,923.0
Ran intercepts by participant/choice set + ran slope for saccade order by participant. cov matrix = vc	**40,289.23**	5875.32	**112,903.9**
Ran intercepts by participant/choice set + ran slope for salience by choice set. cov matrix = vc	40,777.00	5877.09	112,925.0
Ran intercepts by participant/choice set + ran slope for salience by choice set. cov matrix = un	40,457.37	5903.38	112,932.4

Bold font indicates the chosen models.

Appendix B

Estimated coefficients for analysis 1. Effects of salience, valence and absolute saccade order on the likelihood of saccadic selection.

Effect	Valence	Salience	Estimate	*SE*	*df*	*t*	*p*
Intercept			−3.282	0.280	11	−11.740	<.0001
Valence	Approach		0.408	0.214	77,877	1.910	0.056
Valence	Avoidance		0.864	0.214	77,877	4.030	<.0001
Valence	Control		0.000	.	.	.	.
Salience		High salience	0.366	0.089	77,877	4.130	<.0001
Salience		Low salience	0.000	.	.	.	.
Valence * salience	Approach	High salience	−0.253	0.114	77,877	−2.220	0.027
Valence * salience	Approach	Low salience	0.000	.	.	.	.
Valence * salience	Avoidance	High salience	−0.271	0.113	77,877	−2.390	0.017
Valence * salience	Avoidance	Low salience	0.000	.	.	.	.
Valence * salience	Control	High salience	0.000	.	.	.	.
Valence * salience	Control	Low salience	0.000	.	.	.	.
Saccade order			0.012	0.002	143	4.850	<.0001
Saccade order * valence	Approach		−0.009	0.003	77,877	−2.640	0.008
Saccade order * valence	Avoidance		−0.011	0.003	77,877	−3.300	0.001
Saccade order * valence	Control		0.000	.	.	.	.
Saccade order * salience		High salience	0.000	0.001	77,877	−0.140	0.885
Saccade order * salience		Low salience	0.000	.	.	.	.
Saccade order * valence * salience	Approach	High salience	0.001	0.001	77,877	0.650	0.516
Saccade order * valence * salience	Approach	Low salience	0.000	.	.	.	.
Saccade order * valence * salience	Avoidance	High salience	0.003	0.002	77,877	1.740	0.082
Saccade order * valence * salience	Avoidance	Low salience	0.000	.	.	.	.
Saccade order * valence * salience	Control	High salience	0.000	.	.	.	.
Saccade order * valence * salience	Control	Low salience	0.000	.	.	.	.

Appendix C

Estimated coefficients for analysis 2. Effects of salience, valence and relative saccade order on the conditional likelihood of saccadic selection.

Effect	Valence	Salience	Estimate	*SE*	*df*	*t*	*p*
Intercept			0.369	0.242	11	1.520	0.156
Valence	Approach		0.768	0.286	7357	2.680	0.007
Valence	Avoidance		1.156	0.282	7357	4.100	<.0001
Valence	Control		0.000	.	.	.	.
Salience		High salience	0.417	0.165	7357	2.530	0.012
Salience		Low salience	0.000	.	.	.	.
Valence * salience	Approach	High salience	−0.172	0.240	7357	−0.720	0.473
Valence * salience	Approach	Low salience	0.000	.	.	.	.
Valence * salience	Avoidance	High salience	−0.442	0.225	7357	−1.960	0.050
Valence * salience	Avoidance	Low salience	0.000	.	.	.	.
Valence * salience	Control	High salience	0.000	.	.	.	.
Valence * salience	Control	Low salience	0.000	.	.	.	.
Saccade order			0.021	0.014	7357	1.430	0.152
Saccade order * valence	Approach		−0.045	0.021	7357	−2.150	0.031
Saccade order * valence	Avoidance		−0.035	0.018	7357	−1.910	0.056
Saccade order * valence	Control		0.000	.	.	.	.
Saccade order * salience		High salience	−0.016	0.017	7357	−0.950	0.342
Saccade order * salience		Low salience	0.000	.	.	.	.
Saccade order * valence * salience	Approach	High salience	0.022	0.025	7357	0.900	0.366
Saccade order * valence * salience	Approach	Low salience	0.000	.	.	.	.
Saccade order * valence * salience	Avoidance	High salience	0.035	0.021	7357	1.650	0.099
Saccade order * valence * salience	Avoidance	Low salience	0.000	.	.	.	.
Saccade order * valence * salience	Control	High salience	0.000	.	.	.	.
Saccade order * valence * salience	Control	Low salience	0.000	.	.	.	.

Appendix D

Estimated coefficients for analysis 3. Effects of salience, valence and relative saccade order on saccadic latency.

Effect	Valence	Salience	Estimate	*SE*	*df*	*t*	*p*
Intercept			1385.530	112.050	11	12.360	<.0001
Valence	Approach		79.006	139.860	6036	0.560	0.572
Valence	Avoidance		−362.200	129.670	6036	−2.790	0.005
Valence	Control		0.000	.	.	.	.
Salience		High salience	−320.500	125.440	6036	−2.560	0.011
Salience		Low salience	0.000	.	.	.	.
Valence * salience	Approach	High salience	−55.713	174.920	6036	−0.320	0.750
Valence * salience	Approach	Low salience	0.000	.	.	.	.
Valence * salience	Avoidance	High salience	121.660	162.170	6036	0.750	0.453
Valence * salience	Avoidance	Low salience	0.000	.	.	.	.
Valence * salience	Control	High salience	0.000	.	.	.	.
Valence * salience	Control	Low salience	0.000	.	.	.	.
Saccade order			−63.138	9.477	135	−6.660	<.0001
Saccade order * valence	Approach		−22.181	13.736	6036	−1.610	0.106
Saccade order * valence	Avoidance		14.673	11.476	6036	1.280	0.201
Saccade order * valence	Control		0.000	.	.	.	.
Saccade order * salience		High salience	28.273	8.238	6036	3.430	0.001
Saccade order * salience		Low salience	0.000	.	.	.	.
Saccade order * valence * salience	Approach	High salience	13.283	14.557	6036	0.910	0.362
Saccade order * valence * salience	Approach	Low salience	0.000	.	.	.	.
Saccade order * valence * salience	Avoidance	High salience	−10.501	11.543	6036	−0.910	0.363
Saccade order * valence * salience	Avoidance	Low salience	0.000	.	.	.	.
Saccade order * valence * salience	Control	High salience	0.000	.	.	.	.
Saccade order * valence * salience	Control	Low salience	0.000	.	.	.	.

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