Attention in value-based choice: Active and passive uncertainty reduction mechanisms

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Abstract

The more one attends to an option, the more likely one is to choose it. This gaze benefit has been formalized as a discounting of unattended options in influential models of decision-making.Recent work shows that the attention benefit vanishes when attention is manipulated externally rather than freely allocated. Here, we explicitly compare free viewing condition, and externally manipulated attention (sequential presentation). Consistent with model predictions, we find strong gaze effects on choice only in free viewing, where people prioritized higher value options. Importantly, this attention prioritization is associated with greater choice efficiency, with more consistent and faster choices. Taken together, our results highlight two ways in which attention shapes choice. First, attention affords option-level value uncertainty reduction by supporting information sampling and value estimation on any attended options. Second, attention affords efficient choice-level uncertainty reduction through prioritization of goal-relevant options.

Keywords: decision-making, cognitive control, sequential sampling, evidence accumulation

Introduction

All else being equal, you are more likely to choose an option the more you look at it. Two types of decision-making models have explained this canonical finding. The intial models instantiate a passive view of attention: Attention operates on information processing. They capture the attention benefit with a discount parameter for the value of unattended options (Krajbich, Armel, & Rangel, 2010) so that ultimately the option that is attended more will more likely be chosen. The alternative view, that information processing guides attention allocation is implemented in newer models (Callaway, Rangel, & Griffiths, 2021; Jang, Sharma, & Drugowitsch, 2021; Gluth, Spektor, & Rieskamp, 2018) (cf. Fig. 1) where attention is correlated with choice because people look at things they consider more likely choosing. Thus, a correlation between attention and choice could arise because attention amplifies value or because value guides attention. These explanations, or their relative contributions, are difficult to disentangle from typical empirical choice data.

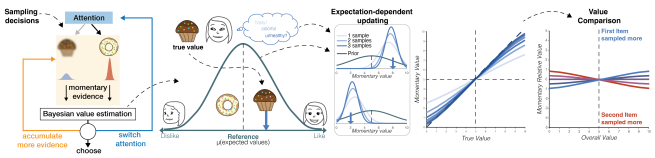

Figure 1: Overview of attention mechanisms.

Here, we combine a sequential presentation paradigm, where attention is manipulated experimentally, independently of value (Frömer, Callaway, Griffiths, & Shenhav, 2022) with the typical free viewing paradigm to assess the impact of active and passive attention mechanisms within the same participants (Fig. 2).

Dissociating active and passive uncertainty reduction mechanisms

Participants (N=45, 29 female, M_{age} = 22.95, SD_{age} = 2.78) made choices among sets of consumer items they had previously rated individually. Choice sets varied in overall (i.e., average) value and value difference. We manipulated attention across trial types: In Free Viewing, both options were shown simultaneously, side by side and participants' attention was measured using eye-tracking. In Sequential Presentation, items were presented sequentially, one at a time and alternated on the screen with relative attention to each item being manipulated via presentation durations (short vs long) (Frömer et al., 2022). In both conditions response hand (left vs right) was coded with colored frames.

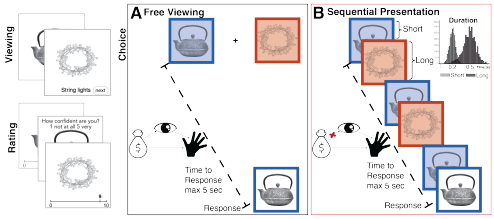

Figure 2: Task Schematic.

Predictions

Key predictions are summarized in Fig 3. We predicted that in Free Viewing trials we would find a strong effect of relative attention on choice. In contrast, in Sequential Presentation, where attention is experimentally manipulated to be independent of value, we should primarily see Bayesian value estimation effects with increased choice probability for high value options that are attended more, but decreased choice probability for low value options that are attended more (Frömer et al., 2022).

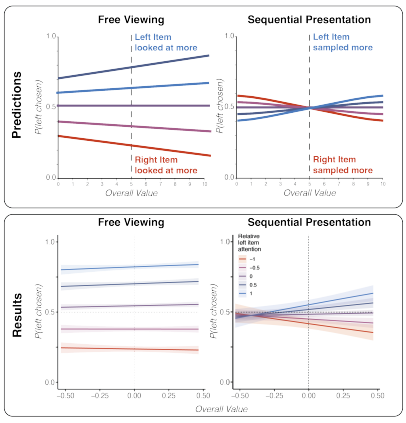

Figure 3: Predicted and observed effects of attention.

Dissociable attention effects in Free Viewing and Sequential Presentation

In line with predictions, we found a significant interaction of trial type with relative attention $b = 1.04$, $CI = 0.73$–1.35, $p < 0.001$ (Fig. 3). Relative attention had a significantly stronger effect on choice in *Free Viewing* $b = 1.32$, $CI = 1.13$–1.51, $p < 0.001$, compared to *Sequential Presentation*, $b = 0.28$, $CI = 0.03$–0.52, $p = 0.027$. Consistent with previous results, we found that in the *Sequential Presentation* condition, participants were more likely to choose the first item they had seen, $b = -0.28$, $CI = -0.42$–-0.14, $p < 0.001$. In line with predictions and previous work (Frömer et al., 2022), we also found that attention effects in this condition varied with overall value, albeit not meeting conventional significance $b = 0.78$, $CI = -0.02$–1.58, $p = 0.055$. However, this interaction significantly varied with order, $b = 1.66$, $CI = 0.06$–3.26, $p = 0.042$, with the predicted cross-over pattern when the right hand option was shown first, $b = 1.61$, $CI = 0.45$–2.78, $p = 0.007$, but not when the left hand option was shown first, $b = -0.05$, $CI = -1.14$–1.05, $p = 0.930$. This result conflicts with previous findings across multiple studies and demands replication. Importantly, consistent with attention cascade effects in *Free Viewing*, participants were less likely to choose the first item they had looked at after controlling for attention $b = 0.27$, $CI = 0.10$–0.44, $p = 0.002$. In a simple model without attention, we found that participants were indeed descriptively more likely to choose the first item they had seen across both conditions, but in free viewing this effect depended on the overall value of options, $b = -0.59$, $CI = -1.05$–-0.12, $p = 0.013$. Thus, only high value options were ultimately more likely to be chosen if they were seen first.

Attention prioritization in Free Viewing

To better qualify attention prioritization in *Free Viewing*, we next analyzed the proportion of attention to the ultimately chosen option as a function of options' overall value and value difference. The *Sequential Presentation* condition served as a reference for the proportion the chosen option would be viewed when gaze could not be actively allocated to that option, e.g, through value amplification effects of attention via Bayesian value estimation. As predicted our results showed that view proportion for the chosen option was higher overall in *Free Viewing* compared to *Sequential Presentation* $b = 0.05$, $CI = 0.04$–0.06, $p < 0.001$. In *Free Viewing* only, this proportion increased with both overall value $b = 0.03$, $CI = 0.00$–0.06, $p = 0.022$ and value difference, $b = 0.04$, $CI = 0.01$–0.07, $p = 0.010$ (Fig. 4). Suggesting that in these conditions the high(er) value option was more readily identified and prioritized. We found that in *Free Viewing* participants looked more at the chosen item when value difference was greater, $b = 0.02$, $CI = 0.00$–0.05, $p = 0.031$, and when overall value was higher, $b = 0.04$, $CI = 0.02$–0.06, $p < 0.001$, but there were no significant relationships with value difference, $b = -0.01$, $CI = -0.04$–0.01, $p = 0.215$, or overall value, $b = 0.01$, $CI = -0.01$–0.03, $p = 0.476$, in *Sequential Presentation*. Taken together these results show that the canonical gaze-choice correlation is overwhelmingly driven by attention prioritization.

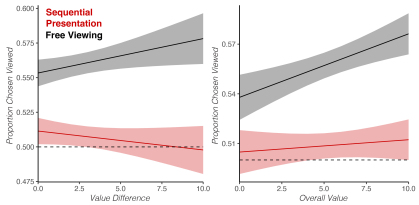

Figure 4: Prioritization of the chosen option.

Greater choice efficiency in Free Viewing

We next tested how attention prioritization affected the quality and efficiency of decision-making. Participants made more consistent choices in *Free Viewing* compared to *Sequential Presentation*, in that relative value had a significantly stronger effect in *Free Viewing*, $b = 1.15$, $CI = 0.67$–1.63, $p < 0.001$, $b_{FV} = 3.57$, $CI_{FV} = 2.95$–4.18, $p_{FV} < 0.001$, $b_{SP} = 2.42$, $CI_{SP} = 1.99$–2.85, $p_{SP} < 0.001$. Participants were also faster choosing in *Free Viewing* compared to *Sequential Presentation*, $b = -0.15$, $CI = -0.16$–-0.13, $p < 0.001$, showed significantly greater effect of value difference, $b = -0.12$, $CI = -0.19$–-0.05, $p < 0.001$, $b_{FV} = -0.21$, $CI_{FV} = -0.26$–-0.15, $p_{FV} < 0.001$, $b_{SP} = -0.09$, $CI_{SP} = -0.14$–-0.03, $p_{SP} < 0.001$ and overall value, $b = -0.11$, $CI = -0.17$–-0.05, $p < 0.001$, $b_{FV} = -0.23$, $CI_{FV} = -0.28$–-0.18, $p_{FV} < 0.001$, $b_{SP} = -0.12$, $CI_{SP} = -0.17$–-0.07, $p_{SP} < 0.001$ on RT. Thus, *Free Viewing* choices were more efficient than *Sequential Presentation* choices (Fig. 5).

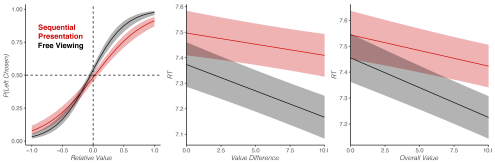

Figure 5: Attention prioritization affords greater choice efficiency.

Conclusion

It has long been debated how attention influences choice (Krajbich et al., 2010; Callaway et al., 2021; Jang et al., 2021; Cavanagh, Wiecki, Kochar, & Frank, 2014; Westbrook et al., 2020). Our results show that the canonical relationship between attention and choice is predominantly driven by attention prioritization. In line with work casting decision-making as a case of optimal information sampling (Callaway et al., 2021; Jang et al., 2021), we find that participants choose more efficiently when they can prioritize compared to when they cannot. This work opens new avenues towards understanding and addressing decision-making challenges, beyond reward processing, in the realm of cognitive control.

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