Insights Into Decisions From Neuroscience and Choice Experiments: the Effect of Eye Movements on Choice

Barbara Kahn, University of Pennsylvania, USA
Jordan Louviere, University of Technology - Sydney, Australia
Claudia Townsend, University of Miami, USA
Chelsea Wise, University of Technology - Sydney, Australia

Our research develops better methods to capture, measure, and understand decision processes by combining brain wave and eye-tracking technology with choice experiments and models. This paper is a first step in examining significant, stable relationships between eye-movements and choice.

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EXTENDED ABSTRACT
Discrete Choice Experiment (DCE) research has predominately been used to observe choice outcomes. However a better understanding of the underlying choice process can help improve our ability to predict choices. Prior work examining choice processes has traditionally used methods such as concurrent or retrospective reporting (verbal protocols), information boards, mouse-tracing methods, or eye-tracking and click stream analysis in computer-based environments. However, these methods face issues of internal and external validity. For example, concurrent reporting consumes mental resources and forces serial processing, limiting external validity. Moreover, many of these measures are unable to capture emotional or automated processes, base state (engagement), or conviction, resulting in compromised internal validity. Thus, there is a need for a better process measurement system for experimental decision making environments that offers both externally and internally valid data.

We proffer that the combination of eye-tracking measures and discrete choice experiments fulfills that need. Eye-tracking has been used to study decision processes in various tasks including probabilistic inference, risky decisions, and advertisements. Indeed, if visual attention and eye movements are coupled, attentional shifts should be related to changes and patterns of eye movements (Hoffman 1998; Rayner 1998). However, eye-tracking observes only information acquisition behavior and not internal cognitive processes. Instead, one must infer underlying cognitive strategies from eye-tracking data. Alternatively, process may be inferred through the experimental design by maximizing the resultant statistical information on cognitive factors influencing choice. For example, choice experiments (Louviere and Woodworth 1983) using full factorial designs allow one to infer certain types of decision rules (Anderson 1971). In this paper we use eye-tracking measures in discrete choice experiments to exploit the benefits these methods offer in understanding preference and choice processing. The broad purpose of our research is to identify empirical generalizations that can be integrated with neuroscience and other literatures.

RESEARCH HYPOTHESES
Consistent with research suggesting individuals are selective in information search (e.g., Bettman, Johnson, and Payne 1991), we hypothesize that individuals quickly look for features and/or feature levels of choice options that best help them discriminate and they focus fixations in areas of a scene that most likely contain information to shorten search length (Rayner and Castelhano 2008).

Hypothesis 1: The time to first fixate on important features is shorter than that for less important features.

Hypothesis 2: Fewer fixations should occur before an individual looks at an important feature compared with the number occurring before looking at an unimportant feature.

In familiar choice contexts, individuals have the ability to isolate that which is most important and task relevant (Alba and Hutchinson 1987). Thus, individuals may focus their visual attention more on choice options or features that require deliberation or a second look than choice options or features that individuals have quickly identified as important.

Hypothesis 3: Individuals spend more time looking at less discriminating features than more discriminating features.

Hypothesis 4: We expect fewer fixations or unique visits for chosen options than for unchosen options. Similarly, we expect fewer fixations or unique visits to attractive, more discriminating features/levels than for less attractive, less discriminating features/levels.

STUDY 1: VISUAL ATTENTION AND CHOICE
In study 1 we a) design, implement and execute a choice experiment that incorporates eye-tracking, b) obtain meaningful eye-tracking measures and c) relate eye-tracking measures to choices.

Method
We used a Tobii X60 eye tracker. The experiment focused on choices of cracker options described by combinations of three features: shape (circle, square, triangle), flavor (wheat, dark rye, plain) and topping (salt, poppy, no topping). We selected nine cracker descriptions from the 3^3 factorial using a main effects design. Following Louviere et al. (2008) we used a balanced incomplete block design to assign the crackers to 12 choice sets, each containing three crackers. The 12 sets of crackers were displayed one set at a time, and 14 participants chose their most and least preferred cracker for a party they would host.

Results
Table 1 gives the results from stacking all the participants’ choices (Horsky and Rao 1984) and estimating an aggregate conditional logit model (McFadden 1974) including the effects of eye-tracking measures as covariates. Although preliminary, the results are promising, suggesting the visual attention measures are systematically associated with choices.

Specifically, ‘time to first fixation’ was significant ($B_{time\ to\ first\ fixation} = -.3190, p < .05$), implying the longer to fixate on a choice option the less likely it is chosen. ‘First fixation duration’ also was significant ($B_{first\ fixation\ duration} = 2.100, p < .001$), implying the longer one initially fixates on a choice option the more likely it is chosen. The latter result supports the notion that individuals quickly look for features/feature levels of choice options that help discriminate choice options. Finally, ‘visit count’ was significant ($B_{visit\ count} = -.408, p < .05$), implying fewer unique visits to more attractive than less attractive choice options. Thus, the results suggest eye movements play a non-trivial role in choice.
### TABLE 1

<table>
<thead>
<tr>
<th>Attribute effects</th>
<th>est. b</th>
<th>s.e.</th>
<th>t-stat</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Round</td>
<td>0.1821</td>
<td>0.1507</td>
<td>1.2100</td>
<td>0.2270</td>
</tr>
<tr>
<td>Square</td>
<td>-0.1005</td>
<td>0.1668</td>
<td>-0.6000</td>
<td>0.5470</td>
</tr>
<tr>
<td>Wheat</td>
<td>0.7835</td>
<td>0.1553</td>
<td>5.0400</td>
<td>0.0000 **</td>
</tr>
<tr>
<td>Dark rye</td>
<td>0.0573</td>
<td>0.1434</td>
<td>0.4000</td>
<td>0.6890</td>
</tr>
<tr>
<td>Salt</td>
<td>0.4476</td>
<td>0.1603</td>
<td>2.7900</td>
<td>0.0050 **</td>
</tr>
<tr>
<td>Poppy</td>
<td>0.2118</td>
<td>0.1447</td>
<td>2.0700</td>
<td>0.0370 *</td>
</tr>
</tbody>
</table>

#### The Effect of Visual Attention

| Time to first fixation | -0.3109| 0.1279| -2.4300| 0.0150 * |
| Fixation duration     | -0.1210| 0.2366| -0.5100| 0.6090 |
| Fixation count        | 0.1977| 0.1147| 1.7200 | 0.0850 |
| First fixation duration | 2.1004| 0.7592| 2.7700 | 0.0060 **|
| Visit count           | -0.4076| 0.1411| -2.8900| 0.0040 **|

* p < .05 ** p < .01, results based on the exploded approach to coding
The dependent variable, choice
Reference for the estimate of shapes round and square is triangle
Reference for the estimate of flavors wheat and dark rye is plain
Reference for the estimate of toppings salt and poppy is no topping

#### Summary Statistics

<table>
<thead>
<tr>
<th>Number of observations</th>
<th>500</th>
<th>Log-likelihood intercept</th>
<th>-183.063</th>
</tr>
</thead>
<tbody>
<tr>
<td>LR chi²(11)</td>
<td>89.88</td>
<td>Log-likelihood full model</td>
<td>-138.121</td>
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<tr>
<td>prob &gt; chi²</td>
<td>0.0000</td>
<td>AIC</td>
<td>1.786</td>
</tr>
<tr>
<td>McFaddens r²</td>
<td>0.2460</td>
<td>BIC</td>
<td>-522.165</td>
</tr>
</tbody>
</table>

### STUDY 2: GREATER NUMBER OF CHOICE SETS AND VISUAL ATTENTION

Study 2 builds on study 1 by using a greater number of choice sets to insure participants evaluate each cracker relative to all 27 possible crackers.

#### Method

The stimuli, design and procedure was identical to study 1, except for 18 participants evaluated 57 choice sets. Observing most and least preferred choices in each set provides a complete preference ranking of the three, and allows extrapolation to non-tested choice sets. This method ensures participant-level estimation of the conditional logit choice model (Louviere et al. 2008) required to test hypotheses 1-4. For brevity, individual-level model results are not reported.

### Results

Consistent with study 1, both ‘time to first fixation’ and ‘visit count’ were significant (B time to first fixation = -.953, p < .001; B visit count = -.552, p < .001) and offer the same implications as study 1. There also are fewer unique visits to more attractive cracker features than less attractive features.

### CONCLUSION

This research provides an innovative manner for examining the processing behind choice without the pitfalls of limited external and internal validity implicit in other methods. Moreover, our findings offer strong support that there is, in fact, a strong relationship between eye movements and choice.

### REFERENCES


