13th May 2021

SUMMARY

Hypothesis 1:

- Question: Is there a fundamental difference in how participants visually explored the cue stimulus, in terms of fixations, depending on whether there was high or low perceptual noise?
- Theory: If there cue has a high perceptual noise/uncertainty, there will be a higher degree of stimulus exploration and scanning. This is because the participant scans to get more information so the heat map will have a bigger radius.
- Method: We measure exploration/scanning by heat map radius (bigger radius = more exploration/scanning). This can be plotted against perceptual noise.
- What we have done: So far we have plotted one game for one participant

Hypothesis 2:

- Question: Is there a difference in how participant visually explored the cue stimulus, in terms of velocity of saccades, depending on whether there was high or low perceptual noise?
- Theory: Faster saccades indicate more exploration?
- Method: Plot velocity of saccades against noise.
- What we have done:

Hypothesis 3:

- Question: Does perceptual noise influence inattention to the perceptual cue?
- Theory: If the eye fixation has 'drifted' from the assigned fixation point, then there is a reduced level of attention.
- Method: Measuring the difference between fixation point centre and the centre of the heat map. We can plot stimulus noise (x) against distance from the centre (y)
- What we have done: a scatter plot for gaze speed vs perceptual noise for one participant

?Hypothesis 4: Learning – gaze spread and reaction time could indicate whether the participant is still exploring/whether they have learnt.

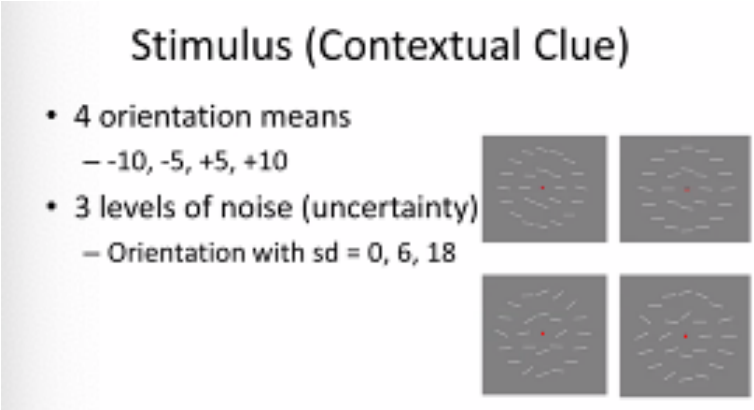
Summary of experiment: (Important for methods section)

- 35 Participants played 18 trials per 16 'games' on a computer in which they had to make a decision as to which option would yield the most valuable outcome
- First, a visual cue was presented which indicated which 'box' a participant had to choose from
- In each box there was a variable and a reliable button (labelled 'V' and 'R')
  Boxes change position (horizontal/verticle) between trials so that the participant doesn't get confused and think they are using the same categories as the previous trial.

- Participants had to choose an option from these which they believed would yield the most valuable outcome (indicated by the highest number/score)

EXPERIMENTAL DESIGN: Within-subjects, repeated measures design (this means that all subjects see all the conditions)
CONDITIONS: The two main conditions are high vs. low *perceptual uncertainty* (uncertainty regarding the stimulus) i.e. the contextual cue was more/less 'noisy' to create different degrees of perceptual uncertainty. This was done by the 'mean angle' of the cue (depicted on this slide). Each GAME is either high/low uncertainty (with two test trials with no noise). The 'third' condition were these no noise test trials.

The key idea is, the decision depends on how certain the subject is about the context! Look at the psychometric response*

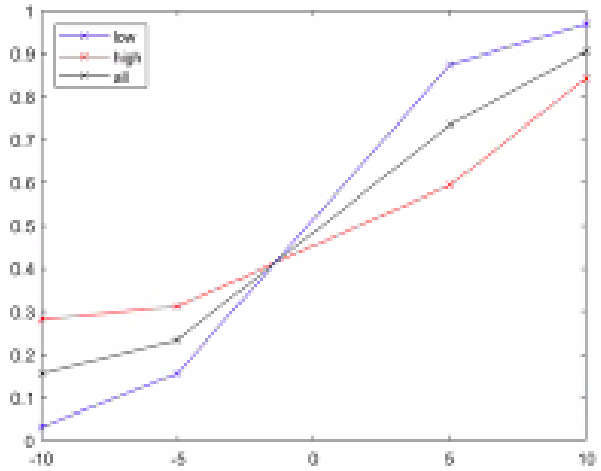


The experiment used 'drop outs' (up to 4) in which subjects didn't respond in time in order to detect subjects not paying attention. There was a certain number of drop outs allocated in each game but if there was more than this the researchers can identify that the subjects aren't focusing. (Clarify this with Andrew)

*Psychometric response: measure response to set of stimulus
Ideally, response certainty depends on orientation AND noise level
X axis = orientations - positive offsets are counter-clockwise orientations
Y axis = probability of getting the right choice Est. number of times answer was 1 divided by number of times condition came up (one box or the other - 1 is one box and 0 is the other) e.g. 'perfect' when counter-clockwise cue identified and select counter clockwise box (??)

Psychometric response

- Ideally, response certainty depends on both orientation and noise level



However, this response may be imperfect due to other factors beyond perceptual uncertainty e.g. motor factors, attentional lapse, memory for category label location.

Slope: overall perceptual uncertainty associated with stimulus category (low/high noise)

Steeper slope means less noise. If the slope is less steep or flat, it would indicate that the participant did not improve in guessing right even when the rotation angle was large and obvious. This would mean that there was more noise making it difficult for the participant to judge.

When there is higher noise, the participant is more uncertain.

Possible limitations:

- Don't have samples from more uncertain cues (only up to 10 degrees) - is it uncertainty or attentional lapse?

There are two models to explain this:

ESTIMATION and CHOICE models.

1) **Estimation**. How are subjects representing the value of each option?
   Is this by a simple average of observed values associated with the buttons? Also maybe a recency bias and memory related effects? Klaman filter (used to find the best estimate of a state in the presence of noise)? Bayesian estimation?

Once the values are estimated, how do you make a choice (with the assumption the participant is trying to maximise the number of points)?

2) **Choice**. How is the choice being made?
   A) (Value) uncertainty induces randomness - softmax with a randomness parameter. When uncertain, it is best to match this i.e. try both options and randomly choose between options until certain of better choice. Increased randomness = increased exploration.
   Can this be due to differences in perceptual uncertainty - people may use a more randomness-based strategy to deal with increased uncertainty. I.e. they match the increased uncertainty with their behaviour.

B) (Value) uncertainty is selectively reduced - directed exploration, UCB algorithm (??). I.e. Choosing the option you are uncertain about in order to reduce this uncertainty. So option is chosen also based on uncertainty.

- interested in the learning process of the estimation

Possible variables to explore

- ➢ Level of 'learning' (indicated by trial number …)
- ➢ Time it takes to make a 'decision' - i.e. when exploring the options ends
- ➢ Visual exploration (eye tracking data, could be indicated by saccades)
- ➢ Response time (click time)
- ➢ Location of pointer on the screen
- ➢ Length of fixation
- ➢ Saccade
- ➢ Trial number
- ➢ Game number
- ➢ Sampling/exploring? How much variability there is in option clicking (as get more consistent answers near the end of games compared to exploration of options at beginning of games).

*To make a hypothesis these are a good place to start! Take two variables and think how they could correlate (e.g. as the trial number increases, visual exploration indicated by saccades decreases). Then think, how can this be scientifically explained (e.g. as the trial number increases, the learning of the correct/most valuable decision has increased. Hence, the participant is visually exploring the options less because he/she has made a decision which yields the most value. This could be explained by reinforcement conditioning as the 'rewarding' high number of an option has reinforced the choosing of that option, reducing the need for exploring alternative behaviours/options).

INITIAL IDEAS:

Saccade vs trial no:

- One could guess that the farther the subject reaches in terms of learning, the more likely that they directly find the important area of the screen at the beginning of the trial and therefore more likely to reduce the saccade per trial

Two variables explored are: 1) trial number/level of learning 2) saccade speed

Decision time vs learning rate

- If the participant's learning curve has a positive slope, decisions would ideally be made faster with each trial. Therefore one can track the clicking delay per trial and see if this is really the case(Milly)
- Decision time decreases over the game (between trials) once a decision has been made
- Learning rate/performance increases = less time scanning/exploring the screen (saccades)

Two variables: 1) decision speed (can look at the pattern and when they settled on a decision) 2) click speed/delay from cue to decision
How could we identify if there is a search? Indirect mouse trajectory to button (how is this related to the eye data?) (Andrew's suggestions)

Can we identify a purely visual search?
**How many turns does it take to memorise the symbols? - Memorised if one doesn't visually search/explore anymore. (Andrew's suggestions)

Fixation time vs trial

- Looking at the evolution of fixation time with each trial
    - Question: What can we correlate this with? What hypothesis can we make?

We could explore how fixation correlates with learning.

a) Learning of the **cue** - how fixation on the correct box increases with learning of the visual cues (by this I mean that once participants have learnt the difference between cues in the two boxes they will fixate on that box more following the correct cue, i.e. they will explore the screen less before the decision - could also be indicated by lower saccades)
b) Learning of the most **valuable** decision - once the participant learnt which option in each box yields the most value, they will spend more time fixating on the valuable/chosen option and less on the least valuable option. We could look at individual trials and compare the fixation in the first half of trials against those in the second half (the half way mark is just an arbitrary indication of decision making - if anyone has another suggestion please feel free to add it!)

Fixation time - reaction time (Andrew's suggestions)
Fixation time vs learning amplitude - is something more informative/surprising fixated on for longer as it is more important.

Est. inattention in stimulus presentation - how many errors are due to inattention?

Saccade vs fixation time:

- Can we hypothesize that if the saccade in each trial becomes less, fixation time per point on the screen will increase? Or should we expect lower fixation time because the participant will make faster decisions?

Learning slope and noise of cue ? Andrew's suggestions

REFINED IDEAS BASED ON OUR MEETING WITH ANDREW:

1. Perceptual uncertainty and exploration : Uncertainty induces choice model of CHOICE: Increased randomness = increased exploration. People may use a more randomness-based strategy to deal with increased uncertainty. I.e. they match the increased uncertainty with their behaviour.

So analysis could observe the degree of orientation and the degree of saccades (indicating exploration)
Alternative factors may be: increased lapse/disengagement when more noise in perceptual cue.
Hypothesise that - as the perceptual uncertainty increases (in more 'noisy' cues), the eye saccades increase (indicating exploration).

Developing our focus on perceptual uncertainty…

15/04 Three ideas suggested by Andrew (these all concern the stimulus not the choice phase):

1) Looking at heat maps of the two different cases of perceptual noise (high vs low) to see if there is a fundamental difference in how participants explored the stimulus (are there different ways that the stimulus was explored?) - radius of circles plotted against perceptual noise level and seeing if there is a correlation
2) Looking at the saccadic pattern (e.g. velocity histograms of eye movements, length of saccades, number of movements etc) and seeing how this statistically differs in cases of high vs low perceptual noise
3) Seeing if we can detect inattention by looking at the time spent in a region of interest (percentage of time on that region during the trial - histogram) in different conditions of high vs low perceptual noise.
    a) Can we reliably detect when someone isn't paying attention?
    b) See if trials with a lower amount of time spend on the stimulus are more likely to be incorrect when discriminating the boxes.