RGC Ref. No.:
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RESEARCH GRANTS COUNCIL
COMPETITIVE RESEARCH FUNDING SCHEMES FOR THE LOCAL SELF-FINANCING DEGREE SECTOR

FACULTY DEVELOPMENT SCHEME (FDS)

Completion Report
(for completed projects only)

Submission Deadlines:	1. *Auditor's report with unspent balance, if any: within **six** months of the approved project completion date.* 2. *Completion report: within **12** months of the approved project completion date.*

Part A: The Project and Investigator(s)

1. Project Title

"Target not found": Explaining negative responses in visual search tasks

2. Investigator(s) and Academic Department(s) / Unit(s) Involved

Research Team	Name / Post	Unit / Department / Institution
Principal Investigator	Chan Ka Ho / Lecturer	Psychology Unit, Department of Social Work, Hong Kong Baptist University, Hong Kong
Co-Investigator(s)	Lee Alan Lap Fai / Assistant Professor	Department of Applied Psychology Lingnan University

3. Project Duration

	Original	Revised	Date of RGC / Institution Approval *(must be quoted)*
Project Start Date	1 January 2016	-	Institutional Approval: 26 Oct 2018
Project Completion Date	31 December 2018	30 June 2019	
Duration *(in month)*	36	42	
Deadline for Submission of Completion Report	31 December 2019	30 June 2020	

Part B: The Final Report

5. Project Objectives

5.1 Objectives as per original application

1. To explicate the proposed theoretical framework by formulating the general computational principles for visual search tasks
2. To perform computer simulations in order to explain existing behavioral data. Computer simulation is especially needed when an analytic solution is not trivial.
3. To test novel predictions of the framework by conducting behavioral experiments. For example, we aim to determine whether the response time distribution of target-absent responses is determined by that of target-present responses.
4. To determine whether detection thresholds for present and absent responses are dependent or not within a specific search setting.

5.2 Revised objectives

N/A

5.3 Realisation of the objectives

In this project, we propose a computational model that explains visual search as an evidence accumulation process based on likelihood comparison. By computer modeling and visual search experiments, we achieved all objectives stated in our proposal.

Objective 1 (*to explicate the proposed theoretical framework by formulating the general computational principles for visual search tasks)*

- We first worked out the transitional probability density functions of evidence accumulation process as outlined in our proposal. The first obstacle we encountered was that an analytical solution for first-passage times was unavailable. We therefore attempted a numerical solution. After gaining some success, we found that this solution was impractical due to some computer precision issues. After these attempts, we fall back to a simulation approach for model fitting.
- Computer simulation results have led us to taking a new approach of modelling decision evidence. We established the mathematical formulae for the reformulated model.

Objective 2 (*to perform computer simulations in order to explain existing behavioral data. Computer simulation is especially needed when an analytic solution is not trivial*)

- First, we implemented a prototype computer model to assess the plausibility of our theoretical framework. Results showed the expected qualitative patterns.
- In the second phase, we adopted a simulation approach to implement our computer model. We also implemented Moran et al.'s (2013) CGS model for comparison. Both were then fitted against Wolfe et al.'s (2010) dataset. Both models successfully produced the desired behavior, but CGS outperformed our model. We examined a range of modifications in order to circumvent limitations and improve model fit, but we reached a plateau after some efforts.
- In the third phase, we reimagined the search process as a process to accumulate decision evidence. A new computer model was developed, which addressed many limitations and substantially improved model fit.

Objective 3 (*to test novel predictions of the framework by conducting behavioral experiments. For example, we aim to determine whether the response time (RT) distribution of target-absent responses is determined by that of target-present responses*)

- Our model sees target-absent responses as a statistical worthlessness to continue searching, with reference to previous experience of successful search. Accordingly, in two experiments, we tested whether target-absent RTs followed target-present RTs while controlling for stimulus factors.
- Experiment 1.1: we varied target saliency over trials while keeping target-absent displays unchanged in order to see whether target-absent RTs varied with target-present RTs. The result was affirmative. This suggests that target-absent response was tuned against target-present trials, and not determined by stimulus factors.
- Experiment 1.2: we tested visual search of three saliency levels in mixed and blocked conditions. Comparing results from mixed and blocked saliency levels, we found that both target-present and target-absent RTs, and false alarms and miss errors, were all tuned against search experience.

Objective 4 (*to determine whether detection thresholds for present and absent responses are dependent or not within a specific search setting.*)

- In a second set of experiments, we check whether prevalence effects on target-present and target-absent responses have the same root. Whereas our model assumes they do, previous studies typically suggest otherwise.
- Experiment 2.1: with two sets of stimuli, we replicated basic prevalence effects on target-absent RTs and response bias. The two effects correlated across individuals, indicating a common basis.
- Experiment 2.2: in theory, our model would expect a target prevalence effect on target-present RTs, but it is not commonly observed in existing studies. In this experiment, we unveiled such an effect by reducing target saliency levels, confirming our hypothesis.
- Experiment 2.3: in this experiment, we found that prevalence effects on target-present RTs correlated with that on false alarm errors. This correlation further confirms a common decision principle for RTs and response bias.

5.4 Summary of objectives addressed to date

Objectives *(as per 5.1/5.2 above)*	**Addressed** *(please tick)*	**Percentage Achieved** *(please estimate)*
1. To explicate the proposed theoretical framework by formulating the general computational principles for visual search tasks	✔	100%
2. To perform computer simulations in order to explain existing behavioral data. Computer simulation is especially needed when an analytic solution is not trivial.	✔	100%
3. To test novel predictions of the framework by conducting behavioral experiments. For example, we aim to determine whether the response time distribution of target-absent responses is determined by that of target-present responses.	✔	100%
4. To determine whether detection thresholds for present and absent responses are dependent or not within a specific search setting.	✔	100%

6. Research Outcome

(P.T.O)

6.1 Major findings and research outcome

In this project we model human visual search behavior as an evidence accumulation process, and our experiment results support this approach. This evidence accumulation process compares the likelihood of whether a target was present, with reference to task knowledge and current perceptual inputs. When the statistical evidence for either possibility reaches a criterion level, a decision is made. In the below, we list the major achievements and findings of this research.

1. A novel approach to formulate visual search

A primary contribution of the current project is that we reformulate the way visual search may be modeled. In general, visual search is modeled as a series of attentional inspections over visual items. In existing studies, different outcome variables are typically mapped to different processes and stages. For example, depending on specific formulations, target-present RTs may be modeled as how fast attention would coincide with the target, target-absent RTs may be based on a mental pace for search termination, and response bias may reflect a bias in per-inspection decision criterion. This modular approach assumes little relationship between these outcome variables, and these variables co-vary only because they face the same stimulus change. However, our data demonstrate that these variables are correlated even if stimulus variations were controlled, indicating an operational linkage between them. In our reformulation, we take a unified approach to model these visual search behaviors. We model visual search as a single diffusion process that takes into account of the serial deployment of attention, set sizes, and search guidance effectiveness, resulting in a new, integrated diffusion function. This function can therefore model the accumulation of evidence across individual inspections throughout a search, providing a unified explanation to various visual search phenomena.

2. Successful model fitting results

Our model fitted Wolfe et al.'s (2010) dataset very satisfactorily. Even though our fitting statistics remains to be inferior to Moran et al.'s (2013) CGS model, our model still made significant contributions for the novel approach it takes. It successfully models key phenomena including set-size effects, target-presence effects, typical error patterns, and an overlap between target-present and target-absent RT distributions, over a range of stimulus profiles. Importantly, it is more flexible to CGS in terms of its handling of target prevalence effects, response bias, and error RTs. For instance, our model naturally considers target prevalence effects and allows response bias to influence RT, and is superior to CGS on these aspects by design. The CGS only considers stimulus aspects of search, and is inherently incapable to model behaviors produced by search arrangements.

3. Evidence for decision criteria tuned to successful search experience

In Experiment series 1, it is evident that both target-present and target-absent responses were tuned to current search arrangements (difficulty variations, blocking of trials) when stimulus settings were controlled. These findings are less trivial for accounts that consider only stimulus properties. Also, we found correlations between search arrangement effects on RTs and errors across individuals, providing strong evidence for a diffusion-based explanatory framework over a modular approach.

4. Evidence for a common mechanism underlying search termination and response bias

In Experiment series 2, our data demonstrate a relationship between search termination and response bias. This is at odds with previous accounts stating that search termination and target detection are based on independent mechanisms. Also, according to these accounts, target detection is determined by a constant-time (or statically distributed) item inspection process, and thus target-present RTs are generally insensitive to target prevalence. Contrary to these predictions, our data demonstrate that the two processes are linked, and also unveil a prevalence effect on target-present RTs. These results provide clear evidence for a unified explanation for target-present and target-absent responses.

6.2 Potential for further development of the research and the proposed course of action *(Maximum half a page)*

A primary aim for further developing this research is to achieve a model performance exceeding its counterparts. This will be a major milestone in the path to publishing the current work.

A technical constraint of our model is that our diffusion process does not have a trivial analytic solution for its first-passage time. This forced us to rely on simulation techniques. A critical drawback is that it does not estimate first-passage times very accurately. Also, it makes parameter searching imprecise and difficult. Both factors compromise model performance.

To overcome this obstacle, we are working on a mixed simulation-numerical approach by simulating the probability transition (instead of a large number of trials) over discretized time slices and activation levels. Recently, we gained success in obtaining a much more accurate estimation of first-passage time by recovering the absorption probability from transitional probability exceeding the decision boundaries with least-square methods. Obviously, the next step is to apply this method to implementing our model.

There is also room for improvement on the theoretical front. A catch of the current model is that it unrealistically assumes the observer to know the set size before search, and this assumption has several issues. We are currently seeking to drop this assumption and let the model observer to acquire the set size information during search. We shall assess whether this will bring further improvement to model fits.

During the course of our investigation, we also discovered some important shortcomings with CGS. In light of this, we shall reevaluate how our work compares to other models.

Taken together, the above plans warrant another grant applications and shall lead to eventual publications in major journals.

7. Layman's Summary

(Describe <u>in layman's language</u> the nature, significance and value of the research project, in no more than 200 words)

In our everyday lives, we often need to find objects within a scene. This visual search task is a subject of research because it taps into human perceptual and attentional processes. Past research generally focuses on how a "presence" decision is made, leaving little attention on "absence" decisions. This is not surprising given the challenging nature of the problem: whereas the detection of a target can trigger a presence response, there is no simple "trigger" for an absence response.

The current project approaches this problem by considering visual search as a process to acquire "decision evidence". The idea is that the searcher maintains some expectations on how much target signals should be received. At each moment, decision evidence is accumulated for target presence (or absence) if the incoming signal is more likely to come from a target present (or absent) trial.

In this project, we put this idea into a computer model, and found that it models human data pretty well. We conducted two experiment series to test core assumptions of this model, and the results are affirmative. Taken together, this project provides a new perspective to understanding human visual search, which can be useful for improving real-world search tasks.

Part C: Research Output

8. Peer-Reviewed Journal Publication(s) Arising Directly From This Research Project

(Please attach a copy of the publication and/or the letter of acceptance if not yet submitted in the previous progress report(s). All listed publications must acknowledge RGC's funding support by quoting the specific grant reference.)

The Latest Status of Publications				Author(s) *(denote the corresponding author with an asterisk*)*	Title and Journal / Book *(with the volume, pages and other necessary publishing details specified)*	Submitted to RGC *(indicate the year ending of the relevant progress report)*	Attached to this Report *(Yes or No)*	Acknowl-edged the Support of RGC *(Yes or No)*	Accessible from the Institutional Repository *(Yes or No)*
Year of Publication	Year of Acceptance *(For paper accepted but not yet published)*	Under Review	Under Preparation *(optional)*						
N/A	N/A	N/A	✓	Louis K. H. Chan*, Alan L. F. Lee	A Bayesian approach to visual search: a computational and empirical investigation	No	No	N/A	N/A

9. Recognized International Conference(s) In Which Paper(s) Related To This Research Project Was / Were Delivered

(Please attach a copy of each conference abstract)

Month / Year / Place	Title	Conference Name	Submitted to RGC *(indicate the year ending of the relevant progress report)*	Attached to this Report *(Yes or No)*	Acknowl-edged the Support of RGC *(Yes or No)*	Accessible from the Institutional Repository *(Yes or No)*
July / 2016 / Fremantle, Australia	A surround-suppression hypothesis for attentional guidance: Evidence from visual search.	12th Asia-Pacific Conference on Vision	2017	Yes (Attachment 1)	Yes	No
May / 2017 / St. Pete, Florida, USA	Evidence for a common decision mechanism for target-present and target-absent responses in visual search	17th Vision Sciences Society Annual Meeting	2018	Yes (Attachment 2)	Yes	No

10. Whether Research Experience And New Knowledge Has Been Transferred / Has Contributed To Teaching And Learning

(Please elaborate)

Nil.

11. Student(s) Trained
(Please attach a copy of the title page of the thesis)

Name	Degree Registered for	Date of Registration	Date of Thesis Submission / Graduation
Nil.	N/A	N/A	N/A

12. Other Impact
(e.g. award of patents or prizes, collaboration with other research institutions, technology transfer, teaching enhancement, etc.)

Nil.

13. Statistics on Research Outputs

	Peer-reviewed Journal Publications	Conference Papers	Scholarly Books, Monographs and Chapters	Patents Awarded	Other Research Outputs (please specify)	
					Type	No.
No. of outputs arising directly from this research project	0	2	0	0	N/A	N/A

14. Public Access Of Completion Report

(Please specify the information, if any, that cannot be provided for public access and give the reasons.)

Information that Cannot Be Provided for Public Access	Reasons
Nil.	N/A