A Strategy for Uncertainty Visualization Design

Defence R&D Canada

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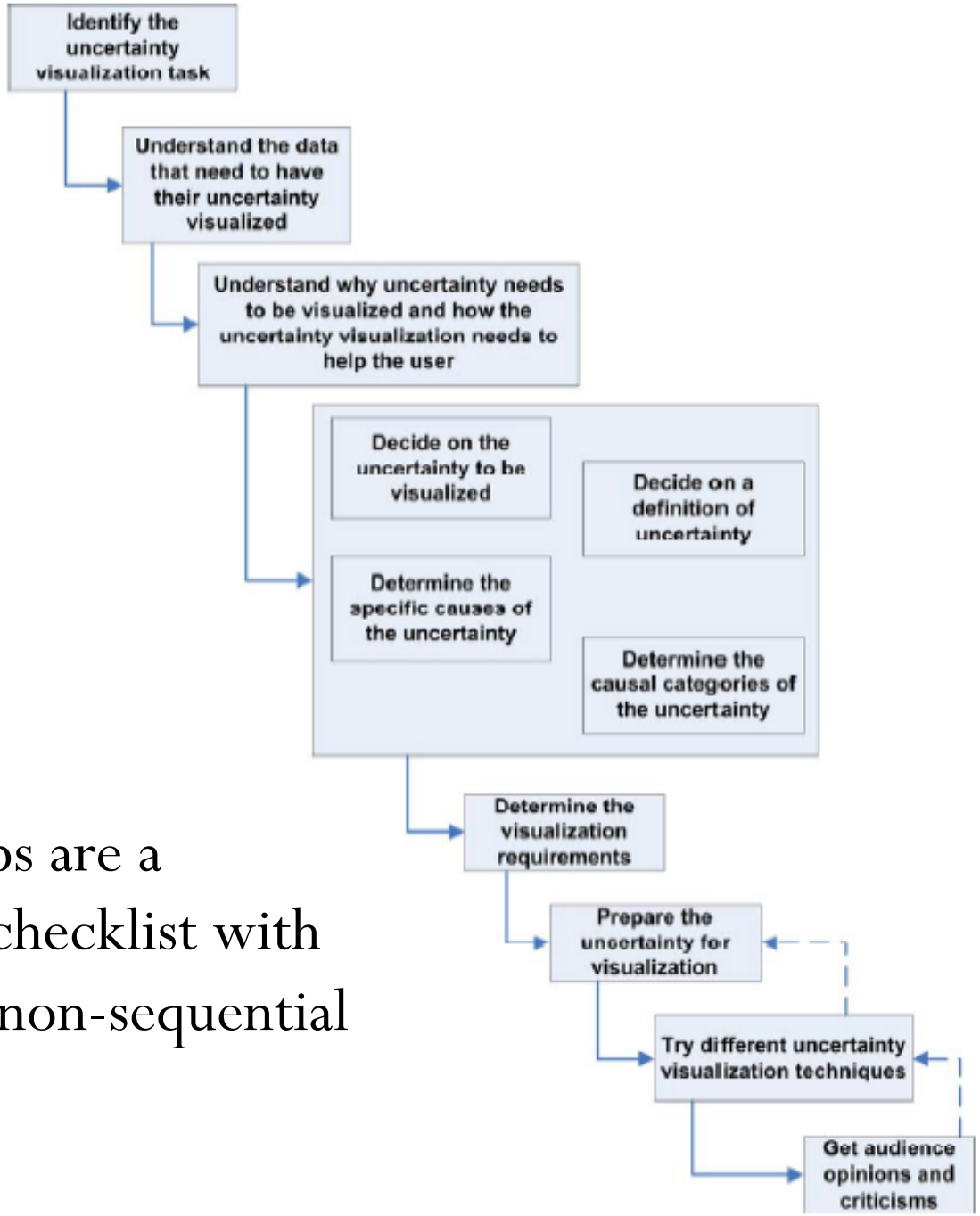
Agenda

- Objective: Determine if we can leverage Defence R&D Canada's work for our *processes* and *design*
- Discussion Points
  - The11 steps
  - Where the steps came from - Overview of their studies
  - High level consideration of *what* and *how* can we *adopt* and *adapt* for our studies

Uncertainty Visualization Development Strategy (UVDS)

- Systematic approach for designing an uncertainty visualization "such that the uncertainty visualization suits the, primary data, the uncertainty being visualized and the user's needs
- Does *not* tell how to create a visualization



The 11 steps are a sequential checklist with embedded non-sequential laundry list

1: Identify an Uncertainty Visualization Task

- A high level generalized description of the task that can be phrased as a problem statement and/or a mission statement
  - Problem statement: "Uncertainty present in the RMP* needs to be visually represented for those who use and build the RMP"
  - Mission Statement: Develop "a visualization technique to enable operators to improve their situation awareness of the maritime surface picture."

* Recognized Maritime Picture (RMP)

2. Understanding the data that need to have their uncertainty visualized

- "Metadata" – speed, heading, name, MMSI number, threat, destination, type, cargo, digital image
- Consider data characteristics such as:
  - Origins – radar, surveillance, self report, voluntary reports
  - Units
  - Precision of numerical values (e.g., within 15m)
  - Modifications made to data (e.g., statistical or derived)
  - Dynamic or static (how often updated)
  - Format (numeric, text, pixels, coded data…)
  - Relationships between data (changes that influence other data)

3. Understanding why uncertainty needs to be visualized and how the uncertainty visualization needs to help the user

- Current RMP does not signal the viewer that there is uncertainty
- Audience and their intents affect how the data should be displayed
  - Uncertainty visualization needs for in-flight air traffic control will differ from scientists studying aircraft traffic patterns – safety vs. statistical analysis

4 -7 – Non-sequential Steps

4. Deciding on the uncertainty to be visualized

   What uncertainty is useful to the task (e.g., *time*, *position* and *identity* in their study)

5. Deciding on a definition of uncertainty

   (e.g., "uncertainty is the dissimilarity between a given representation of reality and the known or unknown reality")

6. Determine the specific causes of the uncertainty

7. Determine the causal categories of the uncertainty

   Categories of uncertainty are related to issues of : timeliness, precision, availability (missing or inaccessible), error (human or machine), ambiguity (multiple meanings or interpretations)

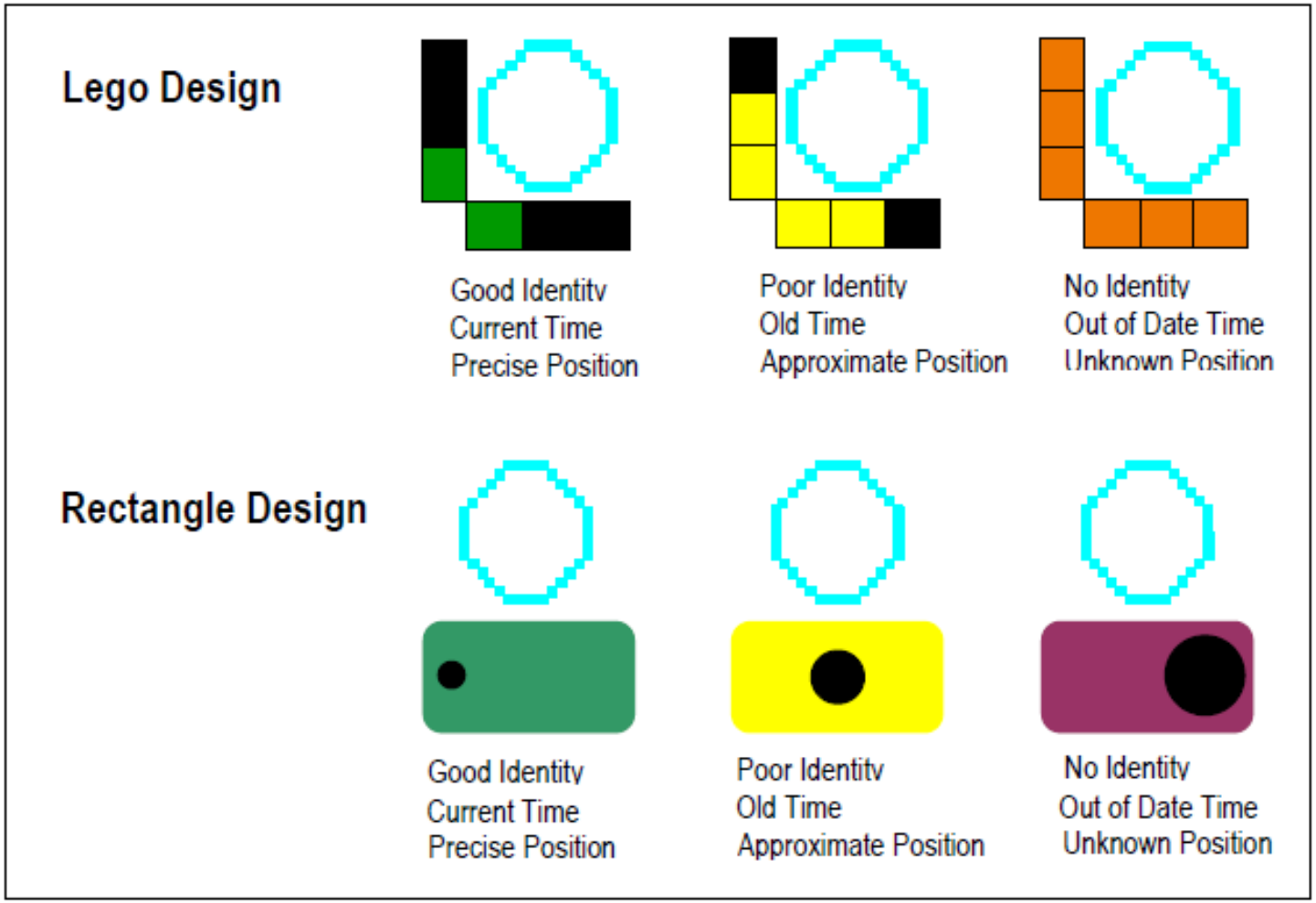
8. Determine the visualization requirements

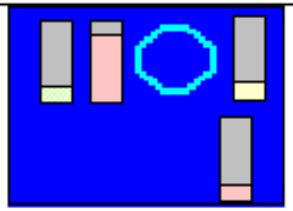
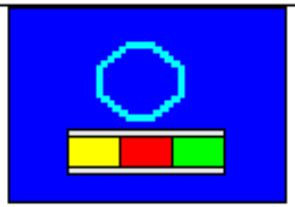
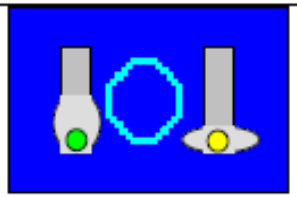
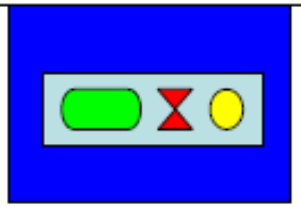
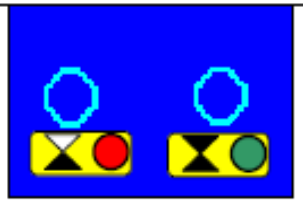
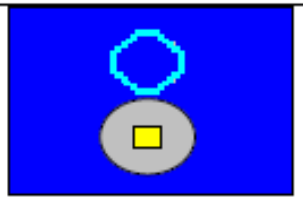
- Provide "enough information to make an educated decision on whether to obtain more information about a contact, a group of contacts or area."
  - Visualization needs to show if there is a problem, but not detailed values of the uncertainty
  - Colors and symbols must not conflict with RMP symbology
  - Representation must be uniquely and immediately understood without additional information or actions
  - Size of symbology must be appropriate for the zoom level
  - Coding should conform to existing psychological constructs and stereotypes

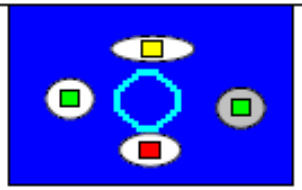
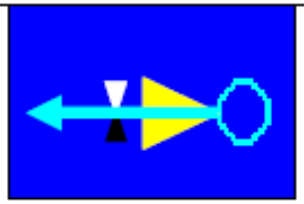
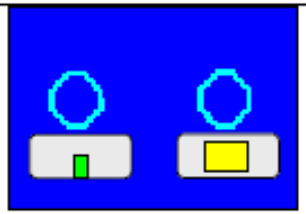
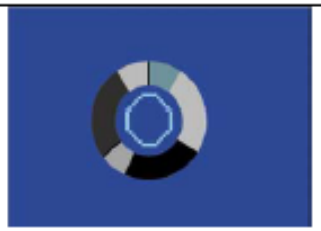
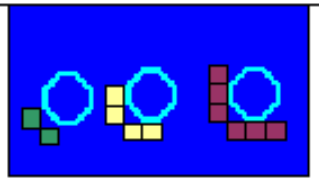
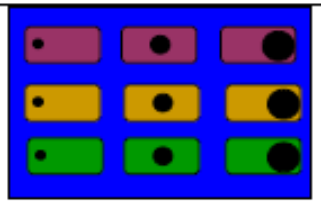
9. Prepare the uncertainty for visualization

- Having "the required uncertainty ready to be used in the visualization"
  - Calculating uncertainty from collected data
  - Assigning uncertainty to levels or categories of data
  - Transforming measurements into proper units
  - Levels of uncertainty represented may depend on the objective of the experiment (e.g., whether testing symbols or levels of uncertainty values)

10. Try different uncertainty visualization techniques



Number	Icon	Identity	Spatial	Time Late
1		Colour	X	Amount of vertical fill
2		Left bar color	Centre bar color	Right bar color
3		Circle color	Width of ellipse	Vertical height on bar
4		Left rectangle color	Circle color	Amount of hourglass fill
5		Rectangle background color	Circle color	Hourglass color
6		Color of square	Size of circle	Color of circle

Number	Icon	Identity	Spatial	Time Late
7		Color of square	Size of ellipse/circle	Color of circle
8		Color of wedge	Angular width of wedge	Hourglass fill
9		Color of small rectangle	Width of small rectangle	Height of small rectangle
10		Amount/color of sector fill	Amount/color of sector fill	Amount/color of sector fill
11		Color of square segment	Number of horizontal segments	Number of vertical segments
12		Colour of background	Size of circle	Position of circle

Sensor Quality and Time

- Sensor quality – cross-hatching or gray solid fill
- Time lateness – border solid/broken; border color green/ gold

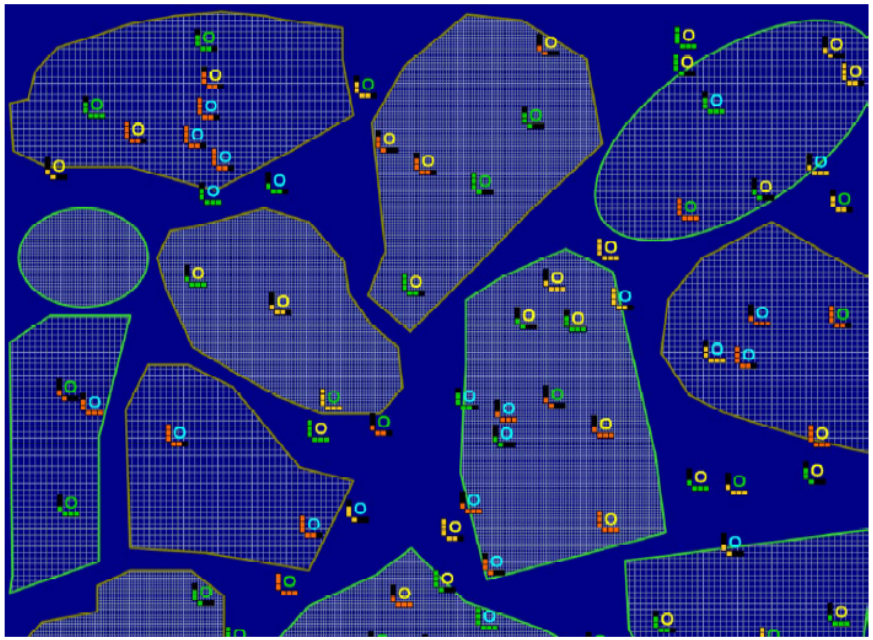


Figure 2: Example screen display with grid and colored border swaths (not to scale) and Lego targets.

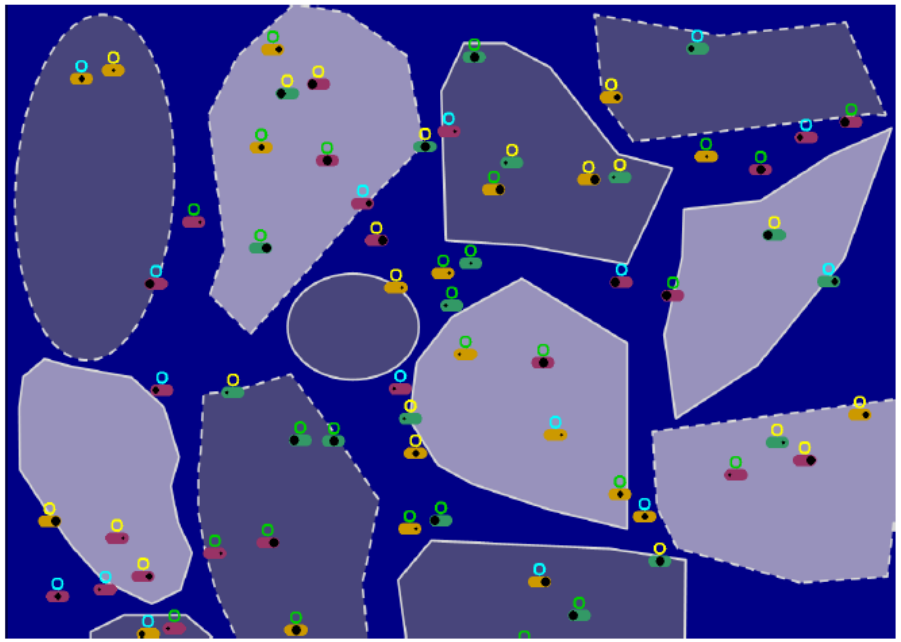


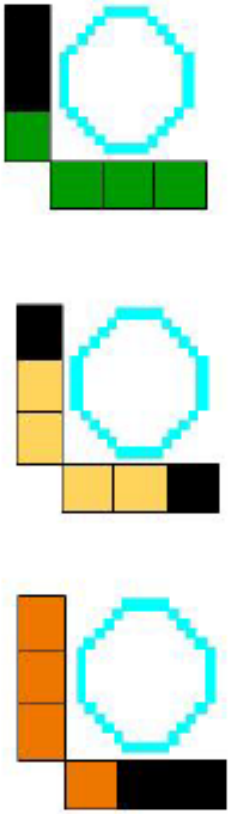
Figure 3: Example screen display with shading and solid/dashed border swaths (not to scale) and Rectangle targets.

11. Get audience opinions and criticisms

Option	Advantages	Disadvantages
Storyboards	• Low time and cost overhead to produce • Portable	• Limited functionality • Low face validity of representations • Only subjective evaluations possible
DRDC Simulation Lab	• Hardware available • Ability to represent high face validity displays • Potential ability to collect human in the loop, quantitative performance data	• Questionable availability of test subjects • High logistical overhead for contractor to implement experiment
Humansystems Test Lab	• Hardware available • Ability to represent high face validity displays • Potential ability to collect human in the loop performance data • Local software development resources available • Local availability of assistants to administer experiment • Available subject pool	

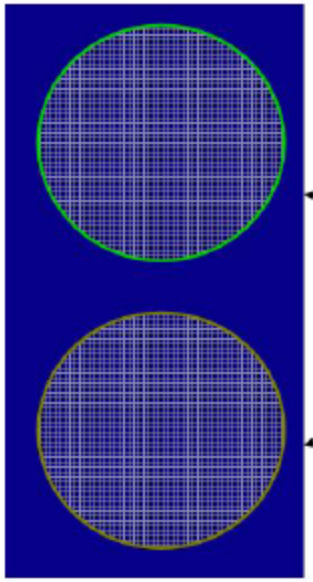
Training

General introduction



- The quality of **IDENTITY** information relating to a vessel is indicated by *colour*
  - **Green = Good** Identity Information
  - **Yellow = Poor** Identity Information
  - **Orange = No** Identity Information
- The quality of **TIME** information is indicated by the number of blocks in the *vertical bar*
  - **One Block = Current** Time Information
  - **Two Blocks= Old** Time Information
  - **Three Blocks = Out of Date** Time Information
- The quality of **SPATIAL** information is indicated by number of blocks in the *horizontal bar*
  - **One Block = Precise** Spatial Location
  - **Two Blocks = Approximate** Spatial Location
  - **Three Blocks = Unknown** Spatial Location
- Now, we will get back to the coverage regions and the types of information associated with those.

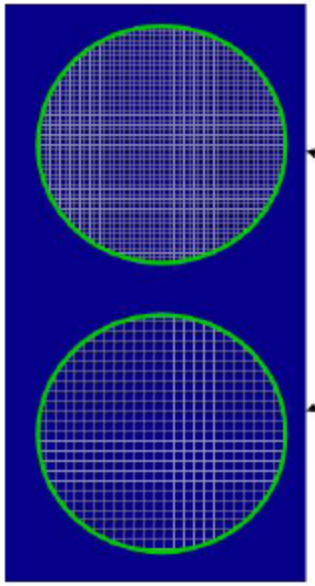
TIME



The **TIMING** information about the coverage region is shown through the **border**

- If TIME information is ***current***, then the border is ***green coloured***
- If we have ***out of date*** TIME information, then the border will be ***gold coloured***

QUALITY



The QUALITY of the coverage of the region is indicated by the coverage region's **fill**

- If the QUALITY of the coverage is ***strong***, then the fill is ***fine grid***
- If we have ***weak*** QUALITY coverage information, then the fill will be ***coarse grid***

1. Completely disagree
2. Somewhat disagree
3. Neither agree or disagree
4. Somewhat agree
5. Completely agree

#	Statement	Response				
1	The different levels of identity information were easy to comprehend.	1	2	3	4	5
2	The different levels of the spatial information were easy to comprehend.	1	2	3	4	5
3	The different levels of the time information were easy to comprehend.	1	2	3	4	5
4	The visual representations of the different levels of the identity information were easy to discriminate.	1	2	3	4	5
5	The visual representations of the different levels of the spatial position information were easy to discriminate.	1	2	3	4	5
6	The visual representations of the different levels of the time information were easy to discriminate.	1	2	3	4	5
7	It was easy to know what to look for when there were multiple criteria	1	2	3	4	5
8	It was easy to find the contacts when there were multiple criteria	1	2	3	4	5

Use the following scale to rate the **workload** you experienced for the areas below:

1. The load was very low and I could do this task continuously with little fatigue
2. The load was moderately low and I could do this task for a few hours at a time
3. The load was noticeable and I would need regular breaks from the task
4. The load was difficult but I could handle it for the duration of the experiment
5. The load was very high and there were times when I would have liked to stop.

#	**Statement**	**Response**				
1	The task of thinking about what to look for based on the search criteria	1	2	3	4	5
2	The task of visually trying to find each contact	1	2	3	4	5

Using the following scale, rate your experience with any of the following symptoms of **visual discomfort** during the course of the experiment

1. Not at all
2. Occasionally, did not bother me
3. Sometimes and it was quite noticeable
4. Frequently and it bothered me
5. A lot and I felt significant discomfort

#	Statement	Response				
1	Dry, itching or sore eye	1	2	3	4	5
2	Blinking	1	2	3	4	5
3	Watery eye	1	2	3	4	5
4	Pain around the eye area	1	2	3	4	5
5	Headache	1	2	3	4	5
6	Other muscle aches	1	2	3	4	5