Poster: Preliminary Investigation of Cognitive Effort in Privacy Decision-Making: Personal Information vs. 3 x 4

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1. INTRODUCTION

Although the dichotomy between privacy attitude and behavior is a well-known problem [1, 11], it is not clear how users make privacy decisions online. We believe that cognitive psychology provides the foundations to better understand privacy decision-making via three established areas: the *dual-process model*, *cognitive effort* and *mental models theory*.

The dual-process model explains cognitive processing via two approaches: *System 1* associated with effortless and intuitive thinking; and *System 2* linked with effortful and analytical thinking that only intervenes at times to endorse, correct and reject decisions [6].

System 2 taps into individuals' limited cognitive effort capacity and changes in pupil dilation act as indication of cognitive effort spent [5].

Mental models are used within HCI to model designs that closely match users' models. Mental models therefore enhance predictability of systems [10]. It has also been linked to dual-process modes of thinking [4].

As discussed in [2], we posit that investigation of the cognitive processes in privacy decision-making will contribute towards explaining the un-usability of online privacy designs. We present a preliminary study investigating users' cognitive effort in privacy decision-making.

2. METHOD

The research hypothesis was $\mathbf{H}_1$: *The effort involved in making a set of privacy decisions online is different from that required for a set of representative System 1 tasks.* The *dependent variable* cognitive effort was measured via pupil dilation. The *independent variable* included different tasks consisting of privacy tasks and tasks known to involve System 1 only.

6 participants from our school took part in a within-subject pilot study. 2 participants are PhD students and the rest post-doctoral research associates. Eye-tracking data was collected using Tobii X2-30 mounted on a 27" monitor. Verbal responses were recorded via Tobii Studio 3.2.2.

Following established eye-tracking protocol [9], each question was presented for 45 seconds.**Q1** involved multiplication of 2 single digits and **Q2** a visual comparison which is thought to involve System 1 [6]. **Q3** was inspired by Spiekermann et al.'s study on requesting profiling type privacy information when buying a camera [11] while **Q4** referred to sharing a birthday picture versus identifying information (e.g. date of birth). **Q5** was the Stroop test [13] which is known to cause the Stroop effects requiring intentional cognitive effort due to color incongruency [8]. **Q6** was Wason's selection task [14], a widely investigated reasoning problem that is cognitively effortful in its abstract version [3, 12].

2.1 Results

2.1.1 Exploratory Analysis

We plot % pupil dilation against the eye-trackers' recording time as shown in Figure 1. A loading phase leading to a peak period followed by release slope can be observed for each participant. This corresponds to previous research in problem-solving [7]. However, although % pupil dilation dropped quickly for the two simple tasks, it increased into the rest phase.

2.1.2 Regression Analysis

The data did not pass Levene's test for homogeneity of variance, therefore we only use linear regression analysis as an approximation of whether the type of task predicted participants' pupil dilation. The test was conducted on the data for 1 of the participants who produced 90% valid gaze points. The results of the regression model for the left eye are summarised in Table 1 and 2. The model with task as independent variable explained 16.7% of the variance of pupil dilation with $R^2 = .167$, $F(1, 6987) = 1396.366$, $p<.01$. We reject the null hypothesis that there is no significant difference in pupil dilation between a specific set of privacy decisions and representative System 1 tasks. However we cannot make conclusive inferences. The large unexplained % variance could be caused by noise in the data or other arousal factors which were not controlled (e.g., visual processing, luminance, anxiety and stress).

2.1.3 Fourier Analysis

We used FFT in Matlab to conduct a frequency-domain decomposition and plotted a waterfall graph. From Figure 2 we observe that our data lie at the low frequency part of the graph with noise potentially contributing the high frequency part of the signal (i.e. higher than 1.5Hz).

3. DISCUSSION

It appears that the 2 privacy tasks might not call for similar cognitive effort as intuitive and effortless System 1 tasks. However we believe the following enhancements are key to more controlled experiment design and pointed explanations: **1.** start the experiment with a rest period to avoid anticipation effect for **Q1**; **2.** measure loading and release rate and duration of peaks; **3.** control task complex-

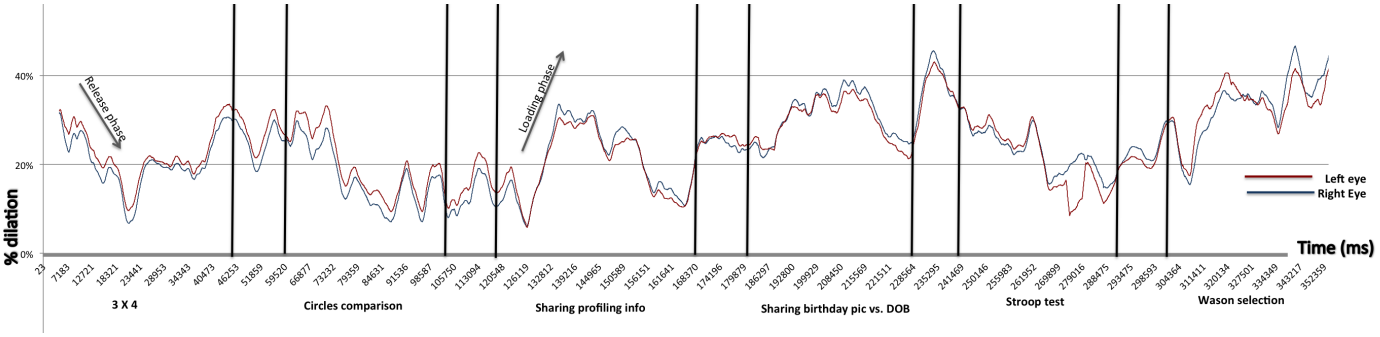

Figure 1: % pupil dilation for the series of tasks

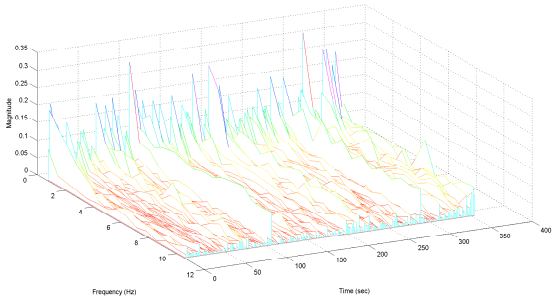

Figure 2: Waterfall graph

Table 1: Regression model summary

Model	R	R Sq.	Adj. R Sq.	Std. Error
1	.408	.167	.166	9.23850

ity and establish effect of question length; **4.** control for accomodation effects (e.g. point of fixation between tasks, luminance and visual angle); **5.** randomise tasks to avoid order and confounding effects from fatigue and ego depletion; **6.** compare pupil dilation in different rest phase settings; **7**. triangulate pupil dilation with fixation at areas of interest, blink rate and saccades data to differentiate reading questions from making a privacy decision.

4. CONCLUSION

We present a pilot study measuring cognitive effort via pupil dilation. The results point to possible difference in pupil dilation between System 1 tasks and the privacy decision tasks. This would indicate that these specific privacy decisions are not effortless or intuitive. However due to the sensitivity of eye-tracking data, confounds and noise, further investigations are required.

5. ACKNOWLEDGMENTS

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6. REFERENCES

Table 2: ANOVA summary

Model	Sum of Sq.	df	Mean Sq.	F	Sig.
Regre.	119179.592	1	119179.592	1396.366	.000
Resid.	596339.243	6987	85.350		
Total	715518.835	6988			

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