Report: Perceiving Colour

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Critical Project 5: Applied Analytics - Data-driven Product Development

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Abstract

This project investigated how colour intensity influences visual attention, with the aim of translating eye-tracking analytics into a data-informed product concept for attention optimisation. Using eye-tracking data captured during gameplay viewing, the study examined how colour-rich and monochrome visual stimuli shape fixation behaviour, dwell time, and spatial gaze distribution. The broader context of this work sits within increasing concerns around visual overstimulation, digital wellbeing, and the need for systems that support attentional regulation rather than passive engagement.

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1 Executive Summary

This project explores how eye-tracking analytics can be applied to the real-world problem of attention optimisation within digital interfaces. The overall goal was to use empirical gaze data to inform the design of a real product concept: an adaptive colour system that dynamically responds to user attention patterns to enhance visual engagement and usability. The project is situated within a user-centred, data-driven design context, combining quantitative and qualitative methods to support evidence-based decision-making.

My role in this project focused on quantitative analysis and project coordination. I contributed as a secondary data collector during the eye-tracking experiments and was responsible for analysing key quantitative metrics, including fixation density, dwell time, and attention distribution across stimuli. In addition, I acted as report coordinator, ensuring analytical consistency, clarity of findings, and alignment with assessment requirements.

The key findings demonstrate that colour stimuli consistently produced higher fixation density and longer dwell times compared to monochrome regions. These results indicate that colour plays a significant role in capturing and sustaining visual attention, supporting its integration into adaptive interface systems.

The demonstration video summarises the experimental process, explains eye-tracking data outputs, and shows how the analytical findings informed the final adaptive colour system concept.

2 Introduction & Context

This project addresses the problem of how colour intensity in visual media influences user attention and engagement, and how eye-tracking metrics can be used to measure and respond to these effects in a practical design context (Holmqvist et al., 2011). While colour-rich digital content is increasingly prevalent, there remains limited understanding of how differences between coloured and monochrome stimuli affect gaze behaviour, such as fixation duration, dwell time, gaze distribution, and arousal-related indicators. The original research questions focused on identifying these attention differences and exploring whether eye-tracking signals could be used to classify levels of user engagement.

This problem was worth addressing because much existing research on colour and attention remains theoretical or descriptive, with limited translation into real product or system design (Bojko, 2013). By moving beyond analysis alone, this project aimed to demonstrate how eye-tracking data can directly inform adaptive interface behaviour, bridging the gap between analytics and applied user experience design.

Following feedback on the initial proposal, the project scope was refined to improve focus and feasibility. Three initial concept ideas were explored before narrowing the direction to the most impactful and analytically meaningful solution. Research questions and hypotheses were refined to better align with measurable eye-tracking variables and to strengthen the link between data collection, analysis, and design outcomes.

The final product concept developed was an attention-responsive smart visual system inspired by smart glasses technology. The system proposes real-time colour adjustment based on user gaze behaviour, demonstrating how eye-tracking analytics can be operationalised into a functional attention optimisation tool.

3 Individual Role & Responsibilities

My role within the team focused on quantitative data handling, analytical interpretation, report coordination, and early-stage UX design contributions. I acted as a secondary data collector during the eye-tracking study, supporting participant sessions once the experimental setup and calibration procedures had been established. While the majority of the data collection design and eye-tracker configuration were led by Aasia Shaikh, I assisted with participant coordination and ensured consistent data capture across sessions.

My primary contribution was in data processing and analysis, specifically relating to the eye-tracking video data. I was responsible for cleaning gaze datasets, segmenting video stimuli, and analysing quantitative metrics such as fixation density, dwell time, and attention distribution across areas of interest. This involved reviewing gaze mappings and comparing coloured versus monochrome regions to identify measurable attention differences. In contrast, qualitative interview analysis was primarily undertaken by Aasia, allowing my role to remain focused on quantitative evaluation.

I also contributed to product prototyping by developing initial UX sketches for the adaptive colour system. These sketches helped visualise how attention-driven colour changes could be implemented within a real interface, supporting the transition from analytical findings to a practical product concept. Aasia was responsibly for the prototype which included a detailed design of the prototype app.

In terms of evaluation and reporting, I acted as report coordinator, structuring written sections, aligning analysis with research questions, and ensuring clarity and consistency across outputs. Research questions, hypotheses, and variable definitions were developed collaboratively, while background research and form creation were largely completed by Aasia.

The video stimuli used in the study consisted of multiple short gaming videos, selected to provide dynamic, realistic content that encourages natural visual attention. Multiple videos reduced stimulus bias and improved reliability, while their length was sufficient to capture stable eye-tracking metrics without causing participant fatigue.

4 Project Execution & Methodological Implementation

This project was executed using a mixed-methods, data-driven approach, combining quantitative eye-tracking analytics with qualitative feedback to inform the development of an adaptive colour system. My contributions were primarily centred on quantitative data processing, analytical implementation, and the translation of analytical insights into design-relevant outputs.

4.1 Data Collection & Processing

Eye-tracking data was captured using Tobii Pro, with recordings processed in Tobii Pro Lab. The Tobii system was selected due to its robustness in capturing naturalistic viewing behaviour and its compatibility with dynamic video stimuli. Tobii Pro enabled frame-accurate gaze mapping, fixation classification, and visualisation of attention patterns across time. Calibration procedures were conducted prior to each session; however, calibration drift and occasional data loss were observed due to participant movement and blink artefacts. These limitations were addressed during preprocessing rather than at the collection stage, ensuring consistency across participants.

While the experimental setup and primary calibration procedures were led by the Aasia, I contributed as a secondary data collector, supporting participant sessions and ensuring consistent recording protocols were followed. Following data capture, my primary responsibility was the organisation, cleaning, and preprocessing of the eye-tracking datasets.

Raw gaze data exported from Tobii Pro was processed using Python and Excel. I developed a Python script to filter out missing or invalid gaze points, resolve timestamp inconsistencies, and standardise gaze metrics across participants. This ensured comparability between datasets and reduced noise prior to analysis. Data was organised by participant, stimulus type, and area of interest, allowing systematic comparison between coloured and monochrome regions.

Key quantitative metrics included fixation density, dwell time, and gaze distribution. Fixation density was used to identify areas of concentrated visual attention, while dwell time measured sustained engagement with specific regions. These metrics were selected because they provide objective indicators of attentional allocation, which is critical for evaluating attention optimisation. Assumptions underlying the analysis included consistent stimulus exposure across participants and the validity of fixations as proxies for visual attention.

Quantitative eye-tracking data alone indicates where and for how long participants looked, but not why. For this reason, qualitative interview data was collected alongside gaze metrics. Qualitative responses were used to contextualise attention patterns, clarify user intent, and support interpretation of ambiguous gaze behaviours.

Ethical compliance was maintained throughout the study. All participants provided informed consent prior to testing, were informed about data usage and anonymity, and were free to withdraw at any point in accordance with ethical research guidelines.

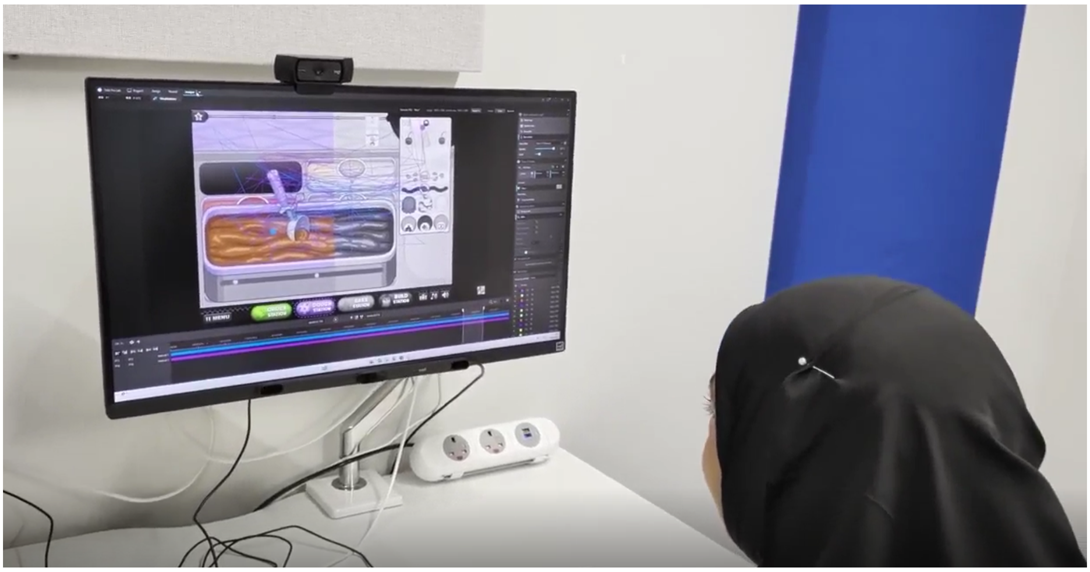

Figure 1: Eye-tracking setup.

4.2 Analytical Methods

Quantitative analysis was conducted using descriptive statistics to summarise fixation density and dwell time distributions. Inferential testing included Welch's t-tests to compare attention metrics between coloured and monochrome stimuli, and one-sample t-tests to assess deviations from baseline attention levels. These methods were chosen due to their suitability for unequal variances and small sample sizes.

In addition to statistical testing, qualitative pattern analysis was applied to gaze visualisations to identify recurring attention behaviours, such as clustering around high-contrast elements or sustained focus on colour-enhanced regions. Visualisation tools within Tobii Pro Lab were used to generate heatmaps and gaze plots, supporting exploratory analysis and communication of findings.

The analytical pipeline consisted of data export from Tobii Pro Lab, preprocessing and metric standardisation in Python and verification in Excel, followed by statistical analysis and visual interpretation. Code snippets and detailed preprocessing pipelines will be provided in a supplementary document to support transparency and reproducibility.

The primary hardware and software tools used included Tobii Pro for data capture, Tobii Pro Lab for initial processing and visualisation, Python for data cleaning and analysis, and Excel for data organisation and validation.

4.3 Product Concept Development

The analytical findings directly informed the development of a conceptual product prototype centred on adaptive colour modulation. While a fully functional system was not implemented, I contributed to the prototyping phase by producing UX sketches and visualisation diagrams that translated attention data into actionable design logic.

The proposed system visualises attention intensity through adaptive colour saturation, allowing key interface elements to dynamically respond to user gaze patterns. Additional design concepts included user-controlled visual filtering and adjustable colour intensity thresholds. These visualisation choices were well-suited to the project as they aligned directly with the observed relationships between colour stimuli and attention metrics.

Observed gaze concentration patterns, fixation durations, and qualitative feedback informed design decisions by identifying where adaptive colour changes would be most effective. For example, regions with consistently high fixation density were prioritised for subtle enhancement rather than aggressive colour shifts.

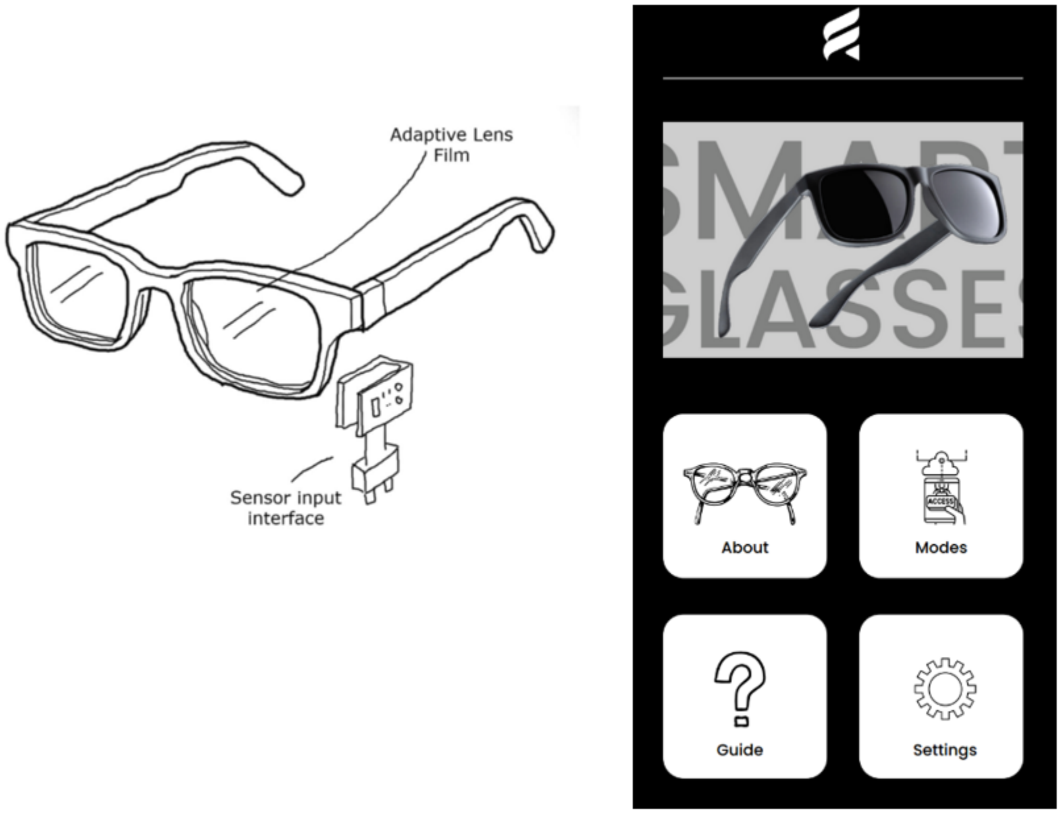

Figure 2: Product sketch and prototype.

Future development plans include implementing the prototype as an interactive dashboard or real-time interface using Python-based visualisation tools. This would allow live integration of eye-tracking data and enable further validation of the adaptive colour system in applied contexts.

Overall, my workflow demonstrates an applied analytics process moving from raw eye-tracking data through rigorous quantitative analysis to evidence-based product design insights, supporting the development of a functional, data-informed attention optimisation concept.

5 Results, Findings & Outputs

The results of this project combine quantitative eye-tracking outputs with qualitative insights to demonstrate how attention data can inform adaptive product design. The findings presented here are drawn from the analysed eye-tracking datasets and supporting qualitative feedback, with detailed data summaries available in the Final Submissions folder.

5.1 Quantitative Findings

Quantitative analysis revealed clear differences in visual attention between coloured and monochrome video stimuli. Across participants, coloured stimuli consistently produced higher fixation density and longer dwell times compared to black-and-white equivalents. Heatmap visualisations showed more concentrated areas of visual attention in coloured conditions, particularly around high-contrast and saturated elements. In contrast, monochrome stimuli resulted in more dispersed gaze patterns and shorter fixation durations.

Figure 3: Example gaze heatmap showing concentrated fixation density on colour-rich stimuli.

Dwell-time analysis further supported these findings, indicating that participants not only noticed coloured regions more frequently but also engaged with them for longer periods. Descriptive statistics and inferential testing confirmed that these differences were consistent across multiple video stimuli, strengthening the reliability of the results. These outputs suggest that colour intensity plays a significant role in capturing and sustaining visual attention, making it a viable control variable for adaptive interface design.

5.2 Qualitative Insights

Qualitative feedback collected post-task helped contextualise the quantitative results by explaining why certain gaze behaviours occurred. Participants frequently reported that coloured elements felt more engaging, noticeable, or "easier to focus" during dynamic scenes. One participant noted, "The coloured version made it easier to know where to look, especially when a lot was happening on screen." Another commented, "The black-and-white clips didn't really stand out to me."

These responses align with the observed gaze data, supporting the interpretation that colour enhances both attentional focus and perceived engagement. Qualitative insights were particularly useful in interpreting ambiguous gaze behaviour, such as prolonged fixations caused by confusion rather than interest.

5.3 Outputs and Design Implications

The primary output of this project was a set of analytical insights that directly informed the adaptive colour system concept. Observed fixation clustering and dwell-time patterns were translated into design logic for adaptive colour intensity, where areas receiving sustained attention would be subtly enhanced rather than visually overloaded.

The attached video presents the full workflow, including the experimental setup, eye-tracking visualisations, comparative analytics, and a walkthrough of the proposed adaptive system. It illustrates how raw gaze data was processed, analysed, and transformed into actionable design decisions.

Overall, the results demonstrate a clear link between eye-tracking analytics and product development, showing how attention data can move beyond analysis to support practical, user-centred design solutions.

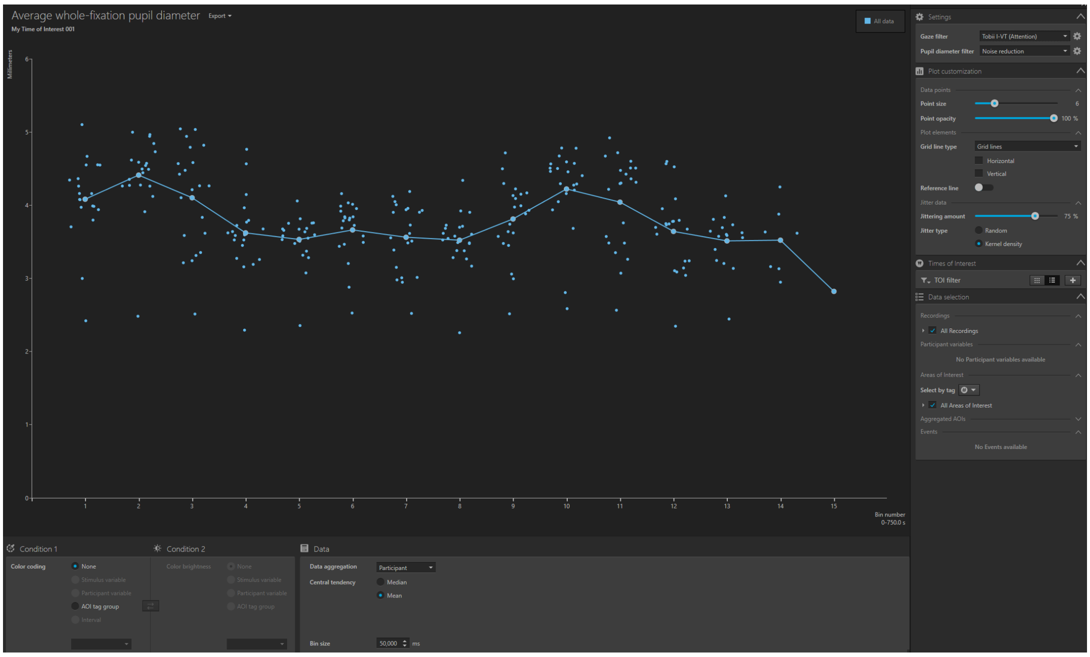

Figure 4: Average whole-fixation pupil diameter (attention).

6 Individual Reflection & Critical Evaluation

This project developed differently in practice compared with the initial plan outlined in Element 1, and reflecting on that shift is important for evaluating both the process and my individual contribution. In the proposal stage, our intended workflow included a broader toolset and a wider range of outputs. However, as we progressed, we made a deliberate decision to narrow the scope and prioritise analytical reliability over complexity. A key example was the decision not to use Plux as originally planned. Instead, we focused the project on Tobii-derived eye-tracking metrics, as these offered clearer alignment with our research questions, reduced integration risk, and allowed more time for cleaning, validating, and interpreting gaze data in a rigorous way. This change improved feasibility and strengthened the credibility of our findings, but it also required adapting my planned tasks to meet the revised analytical priorities.

Several challenges shaped how the work was executed. Technically, eye-tracking data presented inconsistencies that required careful preprocessing. Calibration drift, missing gaze samples, and timestamp discrepancies created risks to comparability across participants and stimuli. I addressed these issues through structured cleaning and standardisation steps, using Python to filter invalid or incomplete data points and to ensure that time-based metrics could be compared consistently across sessions. This was critical because inaccurate preprocessing would have undermined later statistical testing and visual analytics.

A major practical challenge was logistical: I was unable to attend in-person sessions. To manage this, we split responsibilities transparently and communicated consistently online. I contributed as a secondary data collector where possible, but my main responsibility shifted towards quantitative processing, analysis, and report coordination. This redistribution worked effectively because it matched our strengths and reduced bottlenecks; it also ensured that my contribution remained substantial and clearly identifiable despite reduced physical presence. Ethically, the project required careful handling of participant consent and anonymity. Although procedures were agreed collaboratively, maintaining ethical compliance required consistent briefing, clear consent processes, and ensuring data remained anonymised in shared outputs.

A key learning outcome was developing a more realistic understanding of how HCI devices and analytics operate within product development constraints. Eye-tracking tools provide rich quantitative data, but they also introduce practical limitations, including calibration sensitivity and ambiguity in interpretation. The most valuable lesson was that eye-tracking metrics are most meaningful when triangulated: quantitative patterns indicate what participants attended to, but qualitative reasoning is necessary to interpret why those patterns occur. This reinforced the importance of using mixed methods when translating behavioural data into design decisions.

Reflecting on teamwork dynamics, our collaboration was generally strong and task ownership was clear. During Element 1, we worked closely to define research questions, hypotheses, and variables, which gave the project a coherent analytical direction. As the project progressed, each member contributed in distinct ways, and the communication structure helped maintain alignment despite working remotely at times. The final outcomes reflect this collaboration: the project successfully moved from gaze analysis to a grounded product concept rather than remaining at the level of descriptive results.

My work added distinct value by ensuring the quantitative pipeline was robust and interpretable. The final outputs depended heavily on reliable cleaning, metric standardisation, and clear analytical synthesis, which I led. For future improvement and scalability, the project would benefit from a larger participant sample, more controlled calibration checks during sessions, and expanded stimulus variation (e.g., multiple colour intensity levels rather than binary coloured vs monochrome). If developed further into a functional system, the adaptive colour concept could be implemented as an interactive prototype and validated through usability testing to measure real performance impact beyond attention metrics.

7 Conclusion

This project successfully demonstrated how eye-tracking analytics can be applied to investigate visual attention and translate empirical findings into product-relevant design insights. My primary contributions focused on quantitative data processing, analytical interpretation, and the synthesis of results into clear, evidence-based conclusions. Through structured cleaning, standardisation, and analysis of eye-tracking metrics, I helped ensure that the findings were reliable, interpretable, and aligned with the project's research objectives.

The results showed that colour-rich stimuli consistently generated higher fixation density and longer dwell times than monochrome content, indicating stronger and more sustained visual engagement. These findings are significant because they move beyond confirming known relationships between colour and attention, instead demonstrating how specific gaze metrics can be operationalised to inform adaptive design logic.

From an applied analytics perspective, this work illustrates the value of combining quantitative metrics with qualitative context to support robust interpretation. Rather than treating eye-tracking outputs as isolated measurements, the project used multi-metric analysis to guide practical design decisions. This approach contributes to data-driven product design practice by showing how behavioural analytics can inform adaptive systems, such as attention-responsive visual technologies. Overall, the project reinforces the importance of analytical rigour, methodological transparency, and user-centred interpretation when applying data analytics to real-world product development challenges.

References

Agnieszka Bojko. *Eye Tracking the User Experience: A Practical Guide to Research*. Rosenfeld Media, New York, 2013.

Kenneth Holmqvist, Marcus Nyström, Richard Andersson, Richard Dewhurst, Halszka Jarodzka, and Joost van de Weijer. *Eye Tracking: A Comprehensive Guide to Methods and Measures*. Oxford University Press, Oxford, 2011.

Appendices

Please refer to the shared file to access the ethics forms, consent forms, data samples, and code snippets.