Affective Colour Palettes in Visualization

Abhisekh Patra  †
School of Interactive Arts & Technology,
Simon Fraser University

Lyn Bartram  ‡
School of Interactive Arts & Technology,
Simon Fraser University

Maureen Stone  †
Tableau Software, USA

ABSTRACT
The communication of affect, a feeling or emotion, is central to creating engaging visual experiences. We report research into how different colour properties (lightness, chroma and hue) contribute to different affective impressions in information visualization applications. Our results provide initial evidence that colour properties can be manipulated to achieve affective expressiveness in information visualization.

Keywords: Affective Visualization; Colour Perception; Design

1 INTRODUCTION
We react affectively as well as cognitively to visual imagery [8]. This is important in visualization for supporting the communicative intent [1], engagement, and problem solving [5]. While it is often considered as emotion, other experiential responses such as those used in marketing and journalism are important for visualization designers; notably those to do with trust [2] and data storytelling [1]. We selected eight affects to explore for colour association: Positive, Negative, Calm, Exciting, Serious, Playful, Trustworthy and Disturbing. The first four are drawn from common models of emotion [11]. The latter four chosen as feasibly useful in visualization applications. Designers are skilled in using colour to communicate affect but this is largely rooted in professional craft and qualitatively rather than empirically validated. There are few computationally tractable models that define how to use colour in information visualization to enhance affect. We are interested in whether we can capture affect as properties of a colour palette in simple visualizations, and to what degree we can characterize palettes of colours for affective impact. We studied how different palette properties influenced affective impressions. Our results show that perceptual colour properties (hue, chroma and lightness) and palette composition (hue clusters, hue dispersion) differ by affect. These results contribute to operational guidelines for affective colour palette design.

2 BACKGROUND
Research has established consistent colour naming and semantic associations [7, 9, 10]. These algorithms explore the rich associations grounded in concept-colour relations but have not been applied to more nuanced forms of affect. There is substantial evidence of the impact of individual colour on affect. For example, warm colours have been shown to be more physiologically stimulating than cool hues of blue and green [3]. Red is considered hot, vibrant and intense across cultures [3] and most likely to induce arousal and anxiety. Blue is considered serious while yellow contributes to impressions of unprofessionalism [2]. While there are many design-oriented approaches to organizing colours into palettes (e.g. ColorBrewer [6])) there are no rigorously validated models of affective palettes for visualization.

3 STUDIES: AFFECTIVE PALETTES
In an initial image analysis of 12,000 images from Flickr and DeviantArt, mostly abstract, we found distinct differences across our affective tags. We expanded queries by using synonyms for the affective words to build an image dataset. We had two objectives first to determine if there were consistent colour properties associated with affective tags, and second if there were consistent patterns of colours use. We then applied these to development of colour palettes for further studies. We calculated all colour properties using CIELAB. For each image we calculated aggregate mean L* (lightness) and chroma. We then computed distribution of these by using histograms with a bin size of 10 for each. We found Calm, Playful and Exciting images were lighter than Disturbing and Negative. Negative and Calm were less colourful than Playful and Exciting.

With lightness and chroma results from the analysis we generated a set of 40 distinct hues for each affect category. Following the work of Lin et al [9] each hue was measured against the set of different images that were categorized by affect. We then selected the most weighted and distinct colours to fit across affects. Calm and Trustworthy images had higher concentrations of blues and greens; Playful and Exciting had more highly saturated colours - reds, vibrant greens and blues. Disturbing had a larger distribution of dark browns, blues, reds and black. Negative used more grey and muted browns.

In order to determine whether these results would transfer to visualization contexts, we ran two experiments in which users created affective palettes for simple visualizations using colours derived from this analysis. An expert in visualization colour design refined colours by clustering to optimize saliency and distinctiveness to build a set of candidate colours that captured the range. Participants selected five colours for two categorical visualizations (bar chart or map). The goal was to see whether users would consistently assign different colour palettes for each of our 8 affective categories. Our study included designers (49) and non designers (172). In the first experiment 37 colours were available; based on its initial results we added 4 additional dark colours to the second study to increase the expressivity of the palettes. After selecting the palette, participants rated their satisfaction with how well the colours expressed the affect on a sliding scale from 1 to 10.

4 METRICS
We characterized palettes with two kinds of metrics. Aggregate perceptual properties were mean L* and chroma. For colour distribution we used an aggregate measure of saturation-weighted hue distribution [4] to capture hue in the a*b* projection of the CIELAB space. The actual collections of hues were more difficult to algorithmically define. We simply weighted the use of each colour for each affect.

5 RESULTS
We see differences in both the particular hues chosen for affect and how dispersed the colours are in the resulting palettes. Figures 1 and 2 show examples from our results that highlight some of the
significant differences. The clusters in the left are sorted by lightness. The middle group shows levels of chroma. The right column shows hue clusters calculated by the distance in the CIELAB $a^*b^*$ projection. Calm is lighter than Playful, while Disturbing uses more dark colours. Conversely, both Playful and Disturbing are significantly more saturated than Calm. Calm palettes use more blues. High arousal affects (Playful, and Disturbing) use more reds and yellows. Green was more pronounced in Positive palettes (Playful). Yellow also figured more strongly in Playful, reinforcing [2]. Disturbing palettes contained more dark reds, browns, black and dark blues. Negative and Disturbing palettes used more reds, browns and while Disturbing includes one or two light colours we presume for contrast. While some affects were similar in chroma and lightness, we see differences in hue distance and dispersion. Negative and Trustworthy show trends related to hue. Like Calm, Trustworthy uses more blues, reflecting evidence that these hues relate to peace, competence and trust [2]. The palette is darker overall. At the same time, hue dispersion is greater in these palettes, meaning that there was wider spread (a broader selection of other hues), compared to Exciting and Playful that have a larger concentration of warmer hues (closer to each other in the colour space). Negative, on the other hand, is similar to Disturbing in lightness; both use browns and dark reds. The difference in saturation between the more exciting affects of Playful and Disturbing and the less aroused of Calm and Trustworthy indicate that chroma relates strongly to these impressions. The strong difference in lightness between Calm and Disturbing shows that lightness also influences the impression of intensity. This suggests that palettes with pre-defined hues (such as used in branding) for affects can vary these properties to tune affect. Hue dispersion, and the types of predominant colour family, on the other hand, relate more strongly to valence: the more negative affects used proportionally more browns, dark reds and dark greys, and fewer yellows and greens. Finally, ratings were uniformly high, except for one case in the first experiment where designers were less satisfied with Trustworthy.

6 Conclusion

These studies introduce the concept of affect as a component of visual design and provide a basis for extending semantically resonant palette design to affective concepts. While these results are not in themselves surprising, given research in colour psychology and design practice, they do introduce new dimensions of expressivity to visualization. Our results show, at least in the limited conditions we studied, the relations between perceptual colour properties (hue, chroma and lightness), palette composition (hue clusters, colour dispersion) and affective communicative intent for the eight categories we measured. This extends findings in colour psychology and design practice to the context of simple information visualization forms and palette composition. While preliminary, we suggest this can inform operational features for automatic recommendations of colour combinations for affective communicative intent, and algorithmic manipulations of perceptual properties to enhance affect.

Acknowledgements

The work is supported by NSERC, Natural Science and Engineering Research Council of Canada.

References