Shades of Emotion: How Colour Warmth and Congruency Shape Brainwaves and Emotions

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Master Communication Science

201800100: Master Thesis Communication Science

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22-04-2025

Word count: 13.053

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Abstract

Colour perception plays a crucial role in emotional and cognitive processing, influencing fields such as fashion, marketing, and design. This study examined the neural and self-reported emotional responses to warm, cool, and congruent colour combinations among young adults (N = 25) aged 18–30. Electroencephalography (EEG) was used to record neural responses, including event-related potentials (ERPs) and frequency power (alpha and beta bands) in the prefrontal cortex and amygdala. Participants were tested individually in a controlled laboratory setting using a within-subject design. During the experiment, each participant viewed a series of colour slides on-screen, corresponding to the three experimental conditions (warm, cool, congruent), while wearing EEG caps.

Following the EEG task, participants completed a self-report questionnaire. This included the Positive and Negative Affect Schedule (PANAS) for each condition, capturing changes in emotional affect. Additionally, the questionnaire contained items assessing visual attractiveness, aesthetic balance, satisfaction, harmony, and colour complementarity in response to the congruent colour combinations.

Results indicated that warm colours significantly increased alpha power in both the prefrontal cortex and amygdala, suggesting a modulation of cognitive and emotional processing rather than heightened arousal. Contrary to traditional theories, cool colours did not significantly increase positive emotions, but were associated with a significant decrease in negative affect—suggesting a reduction in discomfort rather than an actively calming or uplifting effect. Congruent colour combinations did not produce the expected emotional balance. Instead, participants reported higher levels of visual complexity and cognitive load, as measured by self-report items on harmony and complementarity.

Methodological limitations, including the fixed order of stimulus presentation and the spatial positioning of congruent colours, may have influenced results. Additionally, ERP responses occur within 100-200 ms, making precise stimulus timing critical for neural accuracy. Future research should consider counterbalancing stimulus presentation and comparing generational differences in colour perception to assess potential shifts caused by prolonged digital exposure.

These findings challenge traditional assumptions about colour–emotion associations, suggesting that such theories may not fully apply within contemporary visual environments shaped by digital saturation. The study offers practical implications for industries that rely on colour psychology, such as fashion and branding, and highlights the need to develop updated models of colour perception that account for evolving cognitive, technological, and cultural influences.

Keywords*:* colour perception, EEG, emotional responses, fashion industry, congruent colours, PANAS, alpha power, beta power, ERP, PSD, visual complexity, cognitive processing.

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Introduction

Neuromarketing techniques, particularly those focusing on colour psychology and design aesthetics, have gained prominence as tools to understand and shape consumer behaviour. These approaches use brain activity to provide insights into subconscious reactions to visual stimuli, offering marketers a deeper understanding of how design elements, like colour, influence emotions and decisions. This is particularly relevant for the fashion industry, where visual appeal is critical in shaping consumer perceptions, moods, and purchasing decisions. In this context, colour plays a dual role: it evokes emotional responses and establishes associative meanings that align with consumer expectations. For example, the use of warm colours, such as red and yellow, can signal excitement and urgency, while cool colours, like blue and green, convey calmness and trust (Elliot & Maier, 2014; Suk & Irtel, 2009).

However, while the emotional associations of warm and cool colours are well-documented, their specific neural impact, particularly within the emotionally driven context of fashion, remains underexplored. Unlike other retail settings, where product choices are driven by utility or price, the fashion industry heavily relies on emotional connections and aesthetic appeal to influence consumer preferences (Singh et al., 2024). Thus, investigating the role of colour in fashion contexts is particularly relevant, as the industry demands a more nuanced understanding of how visual branding can align with consumer expectations and evoke desired emotions.

Additionally, there is limited research on the role of colour congruency in fashion branding. Congruent colour combinations are defined in this study as colour pairs that, while contrasting (e.g., being opposite on the colour wheel), still form a visually harmonious whole. Examples include yellow and purple, red and green, and blue and orange. Such combinations are considered visually striking yet balanced, and they can evoke strong emotional responses (Gupta & Dingliwal, 2023; Luarn et al., 2024). While prior research has examined visual colour congruency in digital marketing contexts, such as product–background combinations on social media (Luarn et al., 2024), its specific effects on brain activity and emotional engagement within the domain of fashion branding remain underexplored.

Although extensive research has been conducted on the emotional effects of warm and cool colours, fewer studies have explored how these colours influence brain activity, particularly in the fashion industry. Brain activity, measured through electroencephalography (EEG), provides a unique lens for examining how the brain processes colour stimuli. EEG captures subconscious and immediate responses by identifying specific brainwave patterns, such as beta wave activity, which indicates heightened arousal, and alpha wave activity, linked to relaxation and calmness (Elliot & Maier, 2014; Khadir & Malik, 2023). These neural responses are critical in understanding the subtle, subconscious effects of colour on emotional engagement in visual contexts where decisions are often rapid and emotionally driven. In the competitive fashion industry, where consumers make quick and often emotional decisions, understanding the neural mechanisms behind these responses could offer brands a significant strategic advantage.

To address this gap, this research will employ EEG-based neuroimaging techniques to explore the influence of colour warmth on emotional responses and brain activity in visual branding. Visual branding in this study refers specifically to fashion designs, such as solid-coloured clothing items and multi-coloured garments incorporating contrasting yet congruent colours (e.g., warm and cool colours paired harmoniously). The central research question guiding this study is: "*To what extent do colour warmth (warm versus cool) and congruent colour combinations in fashion design influence neural responses (e.g., alpha and beta wave activity) and emotional engagement, as measured through EEG?*"

This thesis will focus on three key areas: how warm and cool colours influence emotional and neural responses, how colour congruency modulates these responses, and whether contrasting yet congruent colour combinations evoke distinct reactions compared to solid-coloured stimuli. Solid-coloured designs refer to images featuring a single dominant colour, while congruent colour combinations incorporate complementary colours within the same stimulus. Understanding the differences in how these visual designs influence brain activity will fill a gap in current research and provide actionable insights for the fashion industry.

In conclusion, this study will address the limited use of EEG in visual branding research by investigating how colour warmth and congruency influence brain activity, focusing on brain regions such as the prefrontal cortex and amygdala. By exploring these dynamics, this study seeks to clarify how specific colour stimuli—both as single colours and congruent combinations—affect brainwave activity and emotional engagement. Moreover, by assessing their application on actual clothing, the study provides practical insights into how visual branding shapes consumer behaviour. Integrating EEG data with the domain of fashion branding offers a comprehensive perspective on the neural and emotional mechanisms that underlie consumer responses to colour, generating valuable implications for designers seeking to enhance engagement through strategic colour use.

Theoretical framework

This theoretical framework explores the intersection of neuromarketing, colour psychology, and fashion branding by examining the emotional and neural mechanisms that drive consumer responses to visual aesthetics, particularly colour. The focus is on how warm and cool colours, as well as congruent colour combinations, influence both emotional engagement and aesthetic appreciation. In this study, warm colours are defined as red, orange, and yellow, while cool colours refer to green, blue, and purple. To build this framework, it first outlines the neural processes that underpin colour perception and emotional response, followed by in-depth discussions of colour theory in visual branding and the formulation of hypotheses.

EEG as a tool for studying emotions

Electroencephalography (EEG) is a non-invasive neuroimaging technique used to measure electrical activity in the brain. By placing electrodes on the scalp, EEG detects and records neural signals. Its high temporal resolution makes it particularly valuable in academic research, as it captures brain activity in real time with millisecond precision. This enables researchers to track rapid neural responses to stimuli as they occur, offering a detailed timeline of brain processing. Such precision is essential for studying fast cognitive and emotional processes, revealing how quickly the brain reacts to external inputs such as colour or design stimuli (Zion-Golumbic, n.d.; Winkielman & Berridge, 2004).

Additionally, EEG enables the identification of event-related potentials (ERPs), which are specific patterns of brain activity that occur in response to particular stimuli. ERPs are time-locked to the onset of a stimulus and extracted by averaging repeated EEG segments, effectively isolating the brain's response from background activity (Picton et al., 2000; Luck, 2014). They are characterised by distinct peaks and troughs that reflect different stages of cognitive and emotional processing, including attention, evaluation, and perception. Two components particularly relevant to colour processing are the N100 and P200. The N100 is a negative deflection that appears approximately 80–120 milliseconds after stimulus onset and is associated with early sensory processing and attentional allocation. A stronger N100 response suggests that a stimulus demands greater initial attentional resources. The P200, which appears around 150–250 milliseconds post-stimulus, is associated with emotional and evaluative processing and plays a role in the categorisation of emotional significance. A heightened P200 amplitude indicates that the stimulus is emotionally notable or requires additional cognitive processing.

In addition to ERPs, EEG data can also be analysed using power spectral density (PSD), a method that breaks down the EEG signal into its constituent frequency bands to determine the relative power of specific waveforms such as alpha and beta activity. PSD is particularly useful for assessing sustained emotional states, as it reflects ongoing levels of cognitive arousal and engagement across different regions of the brain. For example, an increase in beta power may indicate emotional arousal or cognitive effort, whereas elevated alpha power is often associated with relaxation and disengagement (Kissler et al., 2006). This frequency-based approach complements ERP findings by offering a broader overview of the brain's state during exposure to colour stimuli.

By explicitly linking the psychological effects of colours and congruency to EEG-based measures—including wave frequency analysis (PSD) and ERP responses—this study outlines a clear framework for understanding how visual branding in fashion designs operates across both subconscious and conscious emotional pathways. This integration highlights how neural mechanisms captured by EEG translate directly into emotional engagement and aesthetic appreciation, offering a deeper, evidence-based understanding of consumer behaviour.

EEG and its relation to colour and emotions

In the context of emotional responses, EEG is instrumental in identifying specific patterns of brain activity linked to different emotional states. As established earlier, alpha waves are commonly associated with relaxation and calmness, often triggered by exposure to cool colours, while beta waves are linked to states of arousal, heightened attention, and emotional intensity, frequently elicited by warm colours (Fell et al., 2010). By capturing these neural responses, EEG provides a deeper understanding of how colour stimuli influence emotional engagement and the underlying brain processes involved. This capability makes EEG a valuable tool for exploring the emotional impact of colour congruency in fashion design, where achieving the right balance of colours can evoke desired emotional responses.

Building on insights from Suk and Irtel about colour warmth and emotions, Khadir et al. (2023) explored the brain activity elicited by RGB (red, green, blue) colour stimuli using EEG analysis. The findings reveal that each colour generates distinct neural responses, with varying brain activity patterns observed at different time intervals after the presentation of each colour. This highlights that our emotional and cognitive responses to colours are not immediate but evolve over time, suggesting that the brain undergoes different phases of processing. For example, an initial response to red may evoke urgency and excitement, while a subsequent response to blue may lead to feelings of calmness and reflection. So, warm colours might initially stimulate arousal, leading to a sense of urgency or enthusiasm, while cool colours might first provide calmness but later evoke perceptions of trust or dependability. This dynamic response is especially relevant to fashion, where garments often combine colours that need to elicit nuanced and consistent emotional reactions. Understanding these phases can help designers create collections that resonate with consumers' emotions across diverse settings, from vibrant social events to serene professional environments.

Building on established research about the emotional associations of warm and cool colours, this section explores their implications for fashion design. In fashion, colours like red, orange and yellow could enhance the appeal of bold statement pieces or energising activewear (Elliot & Maier, 2014; Küller & Mikellides, 1993). Conversely, cool colours are well-suited for designs emphasizing sophistication or comfort, such as professional or casual attire. By strategically leveraging these associations, fashion designers can evoke targeted emotional responses, shaping perceptions of garments' style and emotional tone.

These distinctions in brainwave activity between warm and cool colours provide a basis for understanding how colour perception shapes emotional engagement in fashion branding (Elliot & Maier, 2014; Suk & Irtel, 2009).stss

Warm and cool colours

Colours play an essential role in shaping consumer behaviour, evoking emotional responses that influence preferences, moods, and decisions (Elliot & Maier, 2014). Neuromarketing research highlights the distinction between warm and cool colours as a key factor in driving emotional and cognitive engagement. Elliot and Maier (2014) demonstrated that warm colours are associated with heightened arousal and activation, eliciting feelings of energy and excitement. Similarly, Suk and Irtel (2009) found that these colours evoke emotions such as passion and urgency, making them ideal for scenarios requiring immediate action or attention. Conversely, cool colours are linked to relaxation and stability, offering a sense of calmness that fosters concentration and stress reduction. These findings collectively establish a framework for understanding how colours influence emotional engagement.

Building on these insights, Zhang (2013) explored the application of colour effects in the fashion industry, highlighting how warm tones drive impulse purchases by creating excitement and urgency. In contrast, cool tones were associated with dependability and relaxation, aligning with perceptions of trustworthiness. This complements Suk and Irtel's

(2009) findings, as both studies emphasize the dual role of colour in shaping immediate emotional responses and long-term consumer behaviour. For example, green is often tied to eco-friendliness due to its associations with nature and health, as demonstrated by brands like Whole Foods Market. Meanwhile, black, linked to luxury and sophistication, conveys exclusivity and power, making it a popular choice for high-end brands (Singh et al., 2024).

Associative meanings of colours (in EEG)

Colours in fashion design not only evoke emotional responses but also convey associative meanings that shape consumer perceptions. EEG has proven to be a powerful tool for identifying the neural correlates of these cognitive processes (Kissler et al., 2006). Warm colours are frequently associated with excitement, urgency, or passion, while cool colours are tied to calmness, trust, and dependability. These associations are rooted in emotional valence (positive or negative feelings) and arousal (the intensity of the emotional response), which EEG can effectively analyze through distinct neural patterns.

In addition to conveying emotions, colours also encode symbolic associations that influence consumer perception. The amygdala, central to emotional processing and memory formation, is consistently activated by emotionally charged brand stimuli (Santos et al., 2012a). For instance, a brand that leverages warm colours may elicit energy and enthusiasm, while cool-coloured branding may activate feelings of safety and dependability, reinforcing brand identity. These neural associations are further evaluated by the prefrontal cortex, where symbolic and cognitive interpretations of visual stimuli occur.

Building on the foundational insights of Suk and Irtel (2009), Dael et al. (2016) investigated how individuals associate colours with emotional expressions and found that different colours are consistently linked with specific emotions. The study revealed that participants identified red with anger and passion, blue with sadness, and yellow with happiness. Green was associated with calmness and nature, while purple evoked feelings of creativity and spirituality. This highlights how colour choices can influence perceptions across various contexts, suggesting that colour perception is both culturally and contextually shaped. These findings underscore the potential for fashion brands to strategically select colours that align with desired emotional responses, thereby enhancing consumer engagement and brand identity in a competitive market.

These colour associations extend beyond psychological impressions and have been shown to correlate with measurable neural responses. For instance, Singh et al. (2024) demonstrated that exposure to green enhances feelings of trust and reliability, while black elevates perceptions of prestige, as reflected in distinct EEG activity. Singh et al. (2024) emphasize how different colours elicit distinct neural patterns—excitement, trust, or urgency—supporting the idea that colour strategies influence subconscious emotional engagement via structures such as the visual cortex and prefrontal brain regions. This integration of psychological and neural findings underscores the strategic potential of using warm and cool colours to elicit specific emotional and cognitive responses in consumers. These insights highlight the need for further exploration of how these responses influence branding and purchasing decisions, particularly in industries where visual appeal is critical.

Following the insights provided by Elliot & Maier (2014) on the emotional impact of warm and cool colours, Trimble's (2018) research extends these concepts by exploring how colour priming in retail environments influences physiological responses using EEG and eye-tracking technology. Trimble found that specific colours affect consumers' emotional states and attention, with warm colours driving engagement and decision-making, while cool colours encouraged reflection and calmness. Despite these findings, a research gap persists regarding the integration of neural data, such as EEG, with colour perception in fashion branding, particularly in the context of contrasting colour combinations.

While Trimble's study provides foundational insights into the subconscious effects of colour priming, it primarily focused on general retail settings, where consumer decisions are often guided by utility, price, or convenience. The fashion industry, in contrast, revolves around the design, production, and marketing of clothing and accessories, emphasizing aesthetic appeal, creativity, and emotional connections (Dion & Arnould, 2011). Fashion designs, in particular, use colour as a fundamental tool for storytelling and brand identity, conveying symbolic meanings like sophistication, sustainability, or individuality. This focus on emotional and symbolic connection sets the fashion industry apart from other retail contexts, where colour often plays a more functional or attention-grabbing role (Labrecque & Milne, 2011).

Given these distinctions, it is crucial to investigate how physiological responses to colour warmth and contrast influence consumer behaviour in fashion-specific contexts. Unlike general retail settings, where colour might enhance product visibility or drive quick decisions, fashion designs rely on colour to evoke deeper emotional engagement and align with cultural or personal identity. This suggests that the neural and emotional responses to colour combinations in fashion may exhibit unique patterns that differ from those observed in broader retail contexts.

The forming of hypothesis 1

These theoretical insights lead to the formulation of two core hypotheses, beginning with the influence of colour warmth. Based on the reviewed literature, the first hypotheses propose that consumers' neural and emotional responses are shaped by the warmth or coolness of the colours. Building on findings from Elliot and Maier (2014) and Küller and Mikellides (1993), warm colours such as red, orange, and yellow are expected to evoke heightened emotional arousal and positive moods. These effects are anticipated to manifest through increased beta wave activity and enhanced ERP responses relative to the pre-stimulus baseline, particularly in regions like the prefrontal cortex and amygdala (Elliot & Maier, 2014; Garcia-Rill, 2015; Khadir & Malik, 2023). To capture both subconscious and conscious responses to colour stimuli, the current study combines EEG-based neural measures with self-reported affect scores using the Positive and Negative Affect Schedule (PANAS). This allows for a dual-layered analysis of consumer responses: EEG reveals the immediacy and depth of neural activation, while PANAS provides insight into consumers' subjective emotional states. It is therefore hypothesised that exposure to warm colours will lead to increased self-reported positive affect (e.g., excitement, energy, trust) and reduced negative affect (e.g., confusion, discomfort), as measured by the Positive and Negative Affect Schedule (PANAS).

Hypothesis 1a: Exposure to warm colours will lead to increased beta wave activity, stronger ERP responses, and higher self-reported positive affect (e.g., excitement, energy, trust), as measured by PANAS.

Cool colours such as blue, green, and purple are known to evoke emotional states characterised by calmness, trust, and stability (Elliot & Maier, 2014; Küller & Mikellides, 1993). These emotional effects are anticipated to correspond with increased alpha wave activity and distinct ERP responses in regions such as the prefrontal cortex and amygdala—patterns that suggest a more relaxed neural state compared to the resting-state baseline. These responses align with the trust, dependability, and serenity commonly attributed to cool colours.

Hypothesis 1b: Exposure to cool colours will lead to increased alpha wave activity, distinct ERP responses, and higher self-reported emotional states of calmness, relaxation, and trust, as measured by PANAS.

Colour congruency and its relation to emotions

Colour congruency refers to the harmonious alignment of design elements, creating a unified and aesthetically pleasing outcome that resonates with consumers (Luarn et al., 2024). In fashion design, congruency specifically involves balancing relationships between colours in a garment to evoke complementary emotional responses and enhance overall visual appeal. For instance, yellow, often associated with vibrancy and optimism, when paired with blue, linked to calmness and trust, could evoke a unique sense of balanced energy and serenity. One of the aims of this study is to investigate whether such combinations influence emotional engagement.

While limited research specifically investigates colour congruency within fashion design, valuable insights can be drawn from related fields such as branding and visual marketing. Reber et al. (2004), for instance, introduced the concept of processing fluency, showing how perceptual ease contributes to aesthetic pleasure. Building on this, Luarn et al. (2024) demonstrated that harmonious colour palettes used in Instagram branding enhance both emotional engagement and product perception. These findings suggest that colour harmony not only improves visual appeal but also deepens emotional engagement with consumers. However, while branding studies often focus on static visuals, fashion introduces additional layers of complexity—including tactile interaction, physical movement, and personal or cultural context—which may modulate emotional responses to colour.

Marynenko et al. (2023) provide a more targeted perspective by explicitly addressing colour congruency in consumer evaluations. Their findings show that congruent colour pairings significantly improve perceptions of coherence, garment quality, and overall emotional impact. Although their work is primarily situated within branding contexts, the principles they outline are highly transferable to fashion, where the emotional and symbolic role of colour is even more pronounced. Together, these insights highlight the potential of colour congruency as a strategic design element—allowing fashion designers to not only create visually harmonious garments but also foster deeper emotional connections and strengthen perceived brand value.

The emotional associations of specific colours play a crucial role in how consumers perceive colour combinations in fashion design. Gupta and Dingliwal (2023) highlight that colours such as blue, red, and green evoke distinct psychological responses—blue is associated with trust and dependability, red elicits excitement and urgency, and green conveys eco-friendliness and sustainability. In fashion, these colours can be strategically combined to reinforce brand identity and consumer appeal. However, colour congruency, or the degree to which colours are perceived as harmoniously working together, is essential in determining whether these combinations enhance or detract from the overall aesthetic. When colours are congruent, they can amplify emotional effects and create a cohesive design narrative. In contrast, when they lack congruency, they may lead to visual tension, or negative consumer reactions, such as confusion or discomfort. For instance, a garment featuring green as a dominant hue to evoke nature and balance, complemented by red accents to introduce an energetic contrast, may be perceived as bold and dynamic. However, if the colours are not carefully balanced, the combination might feel overwhelming rather than intentional. This highlights the importance of understanding not only individual colour meanings but also how their interaction influences emotional engagement and consumer preferences.

Achieving harmonious colour combinations in fashion design is essential for creating visually appealing and emotionally resonant garments (Luarn et al., 2024; Suk & Irtel, 2009). Conversely, clashing or poorly matched colours can disrupt the coherence of a design, leading to confusion or negative reactions (Labrecque & Milne, 2011). From a neurological perspective, congruency is thought to ease cognitive processing by aligning visual expectations with emotional outcomes, while incongruent pairings increase neural load as the brain reconciles conflicting signals.

These neural dynamics become more apparent when examined through EEG. Congruent colour combinations—particularly contrasting yet harmonised pairs such as blue and orange or yellow and purple—are believed to evoke a simultaneous interplay of arousal and relaxation. This is reflected in combined beta and alpha wave activity, suggesting a dual-state of activation (Gupta & Dingliwal, 2023). Such combinations may initially induce 'neural tension' as the brain processes opposing signals, before resolving into a harmonised emotional state. This phenomenon is sometimes referred to as a 'crashing' effect, where the visual system is challenged but ultimately satisfied by the contrast. Studies also suggest that congruency reduces cognitive load and promotes aesthetic pleasure through efficient processing (Luarn et al., 2024).

Research using EEG-based neuroimaging supports these findings by showing that warm colours activate brain regions involved in emotion and attention, such as the amygdala and prefrontal cortex (Pessoa, 2008). This aligns with previous research on solid warm versus cool colours, where beta activity corresponds to arousal and engagement, and alpha activity to calmness and reflection. Congruent combinations are therefore expected to activate both systems simultaneously, suggesting a complex neural state of integrated emotional engagement.

The forming of hypothesis 2

Following the exploration of warmth and coolness, the second hypothesis addresses the emotional and neural implications of colour congruency in fashion design. These insights form the foundation of the study's final hypothesis:

Hypothesis 2: Exposure to congruent colour combinations will lead to simultaneous increases in both beta and alpha wave activity in the prefrontal cortex and amygdala, reflecting a combined state of arousal and relaxation (as measured through PSD analysis). Additionally, self-reported PANAS scores are expected to show increases in both positive and negative affective responses compared to baseline. Together, these neural and self-reported indicators *are hypothesised to reflect a harmonised emotional state, which may contribute to more favourable consumer evaluations of the fashion items shown.*

From theoretical foundations to reseach design

EEG research has demonstrated that warm colours activate regions such as the amygdala—central to emotional processing—and the prefrontal cortex, which is involved in aesthetic evaluation and higher-order cognition (Pessoa, 2008). These neural responses support the notion that both warm, cool, and congruent colour combinations in fashion design can elicit strong emotional and aesthetic reactions.

Findings from neuromarketing further highlight how specific colours, such as red or blue, trigger distinct emotions (e.g., urgency or trust) and recognizable neural activation patterns (Santos et al., 2012a; Singh et al., 2024). These associations are not only processed cognitively in the prefrontal cortex but are also deeply embedded in emotional memory structures, influencing brand preferences and consumer loyalty. By integrating insights from branding, neurodesign, and colour psychology, a more comprehensive understanding emerges of how visual strategies shape subconscious consumer responses.

EEG offers a valuable methodological framework for bridging sensory perception with both emotional and cognitive processing, making it particularly well suited to investigate consumer engagement in visual branding contexts (Bazzani et al., 2020). These theoretical insights form the basis for the present study's hypotheses, which aim to clarify how warm, cool, and congruent colour combinations influence both EEG-based brain activity—such as alpha and beta wave patterns, ERPs, and PSD—and self-reported emotional states via the PANAS scale. By combining objective neurophysiological data with subjective emotional reports, this study offers a dual-layered perspective on how colour in fashion branding shapes emotional engagement and aesthetic appreciation.

Building on the theoretical foundation, this study not only examines how warm, cool, and congruent colour combinations influence emotional and neural responses, but also includes an additional research component that applies these congruent colour combinations to clothing designs. In this phase, congruent colour combinations were visually embedded into images of hoodies, allowing for a more contextually grounded investigation of colour perception within fashion branding.

While the stimuli remained digitally constructed, this approach situates colour use within a recognisable fashion format, bridging the gap between abstract colour theory and its aesthetic application. In doing so, the study provides initial insight into how colour congruency might shape emotional engagement when integrated into wearable visual designs—offering relevant implications for visual branding, design, and consumer experience in fashion contexts.

Method

This research follows a within-subject design under controlled conditions to measure brain activity in response to warm versus cool colours, as well as congruent colour combinations, and to examine how these neural responses relate to emotional engagement. EEG will be employed to assess specific aspects of neural functioning, while a questionnaire will be used to capture participants' conscious emotional responses. This approach seeks to enhance understanding of how colour influences consumer perception and emotional engagement. The use of EEG is particularly valuable as it provides direct insights into brain activity, offering a window into how the brain processes information and responds to stimuli—perfectly aligning with my interest in neuroscience and cognitive functioning. Complementing the EEG data, self-reported questionnaires, including the Positive and Negative Affect Schedule (PANAS), will be used to measure conscious emotional states, cognitive engagement, and associative meanings, ensuring a comprehensive understanding of consumer responses.

Research design

The study follows a within-subject design, where each participant is systematically exposed to all experimental conditions, including individual colours, congruent yet contrasting colour combinations, and, in an additional research phase, their application to hoodies. This approach allows for direct comparisons within the same individuals, controlling for variability due to individual differences and increasing the reliability of the findings. Each participant views the stimuli in the same fixed order to ensure consistency across presentations.

Although maintaining a fixed order may raise concerns about learning effects, the potential for such effects is mitigated by the neutral white slide presented after each stimulus. This pause allows neural responses to return to baseline, ensuring that participants' reactions are not biased by exposure to previous stimuli. By standardising the sequence, the study eliminates variability that might arise from randomising the order, ensuring that any observed effects are attributable to the stimuli themselves rather than differences in presentation order.

The independent variables in this study are colour warmth (cool versus warm) and colour congruency (contrasting yet congruent colours). Warm colours include red, orange, and yellow, while cool colours consist of blue, green, and purple. Contrasting yet congruent colour combinations feature the following pairs: red and green, orange and blue, and yellow and purple. All colours are standardised to 75% saturation to ensure consistency. These stimuli are presented in both solid colour formats and applied to realistic clothing designs to simulate real-world fashion contexts, as shown in *Figure 1*.

Figure 1

Congruent colour combinations applied to hoodies

Informed by insights from Hathibelagal's (2025) research on display saturation and its impact on visual performance, this study standardises all colour saturation levels at 75% since his findings indicate that saturation levels above 75% significantly enhance the visibility and distinguishability of colours, even for individuals with congenital colour vision deficiencies. Setting saturation at 75% ensures that colours remain vivid enough to evoke clear emotional and cognitive responses while avoiding excessive brightness associated with 100% saturation. Saturation at maximum levels (100%) may result in overly bright colours that are perceived as warm regardless of their hue, potentially introducing bias in the interpretation of colour warmth and congruency. By maintaining saturation at 75%, this research achieves a balance that supports accurate emotional and neural assessments without overwhelming participants with overly intense visual stimuli.

The dependent variables include both neural responses, measured through EEG, and emotional engagement, assessed via self-reported measures. Neural responses focus on beta and alpha wave activity, capturing states of arousal and relaxation, respectively, along with event-related potentials to track temporal dynamics. Emotional engagement is assessed through the PANAS, capturing arousal-related emotions (e.g., excitement, energy) and calming emotions (e.g., trust, serenity). Additional self-report measures assess visual attractiveness, aesthetic appreciation, and the extent to which the colour combinations evoke a sense of emotional engagement. These outcomes are directly linked to hypotheses 1 and 2, which hypothesized that colour warmth and congruency shape both neural and emotional responses. This experimental framework is designed to examine the direct and interactive effects of colour warmth (warm versus cool), congruency (contrasting yet congruent combinations), and as additional research, their application to fashion designs (on multi-coloured garments) on consumer perception. By systematically evaluating these variables, the study aims to reveal how different colour strategies influence emotional engagement, aesthetic appreciation, and neural responses as measured through EEG.

Participant recruitment

The study will recruit a diverse sample of participants from the target population of fashion consumers. Participants will be selected based on criteria such as age and gender to ensure representation across demographic variables. Participants will be aged between 18–30, as this range is chosen to capture the perspective of young adults in fashion consumption behaviours and preferences. Furthermore, this demographic range allows for exploring potential differences in colour perception.

To ensure the validity of the findings, individuals who are colour blind will not be eligible to participate, as their perception of colours differs significantly from the general population. However, it is acknowledged that conducting a similar experiment specifically tailored to colour blind individuals could yield fascinating insights into how colour perception impacts consumer behaviour in this demographic.

The study recruited 25 participants (11 men and 14 women), with a mean age of 24.0 years (range = 19–30). This sample size was selected to balance logistical feasibility with the need for robust statistical power. Comparable EEG studies investigating colour perception and emotional responses have successfully used similar sample sizes, including Khadir et al. (2023), who conducted their analysis with 12 participants. Within this range, the present study aimed to capture meaningful variation in both neural and emotional responses while maintaining high data quality and manageable analysis procedures. A gender-balanced sample was also ensured to account for possible differences in colour perception and consumer preferences.

Materials

The materials used in this study were carefully selected and standardised to ensure consistency across conditions and to accurately capture both neural and emotional responses. This section outlines the technical specifications of the colour stimuli, the structure of their presentation, and the instruments used to measure participants' reactions.

Stimuli presentation colour settings

To ensure the accuracy and validity of the experimental results, all colours presented in the stimuli—both as solid colours and when applied to hoodies—are maintained with identical RGB settings. This standardisation guarantees that participants perceive the same hues, brightness, and saturation across different contexts, eliminating variability that could affect neural and emotional responses. For example, the solid-colour slides and the corresponding colours featured in the hoodies were derived from the exact same RGB settings, ensuring visual congruence and enhancing the precision of the experiment. This approach helped minimize any potential biases caused by slight variations in colour rendering between different formats.

The following table provides a detailed overview of the RGB and hexadecimal (HEX) values used for each colour in the study:

Table 1

RGB and hexadecimal codes

Colour	RGB Values	Hexadecimal Code	Colour swatches
Red	R: 216, G: 33, B: 33	#D82121	
Orange	R: 214, G: 84, B: 34	#D65422	
Yellow	R: 214, G: 177, B: 53	#D6B135	
Green	R: 22, G: 158, B: 45	#169E2D	
Blue	R: 97, G: 163, B: 221	#61A3DD	
Purple	R: 107, G: 45, B: 207	#6B2DCF	

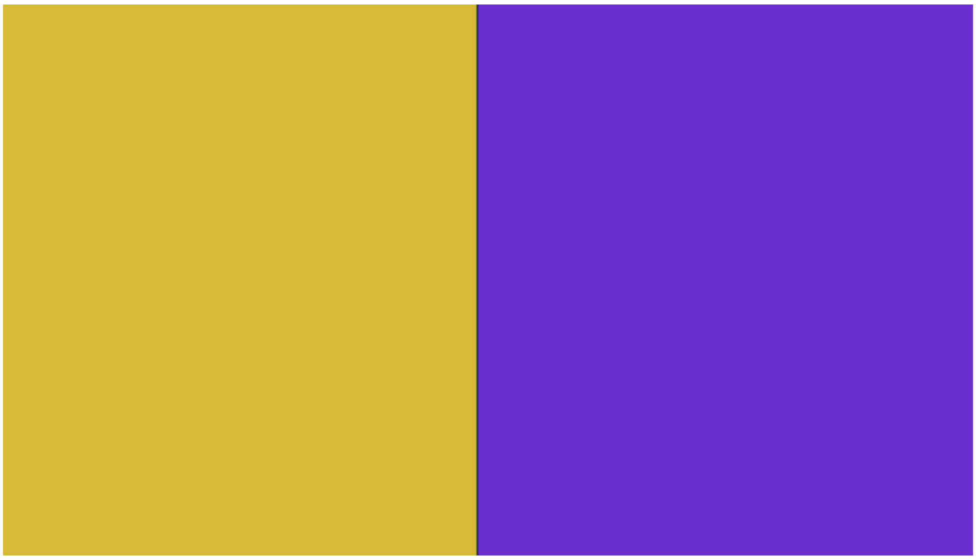
Note. RGB values represent the red, green, and blue colour components, while hexadecimal codes provide their corresponding web colour specifications.

Stimulus sequence and presentation format

Stimuli were presented full-screen for five seconds, followed by a white slide of equal duration to allow brain activity to return to baseline. Solid-colour stimuli appeared full screen, while congruent combinations were shown as split-screen presentations—each half featuring one colour of a complementary pair (e.g., red–green, orange–blue, yellow–purple), as shown in *Figure 2.* This structure ensured controlled exposure while supporting perceptual clarity and neural reset.

Figure 2

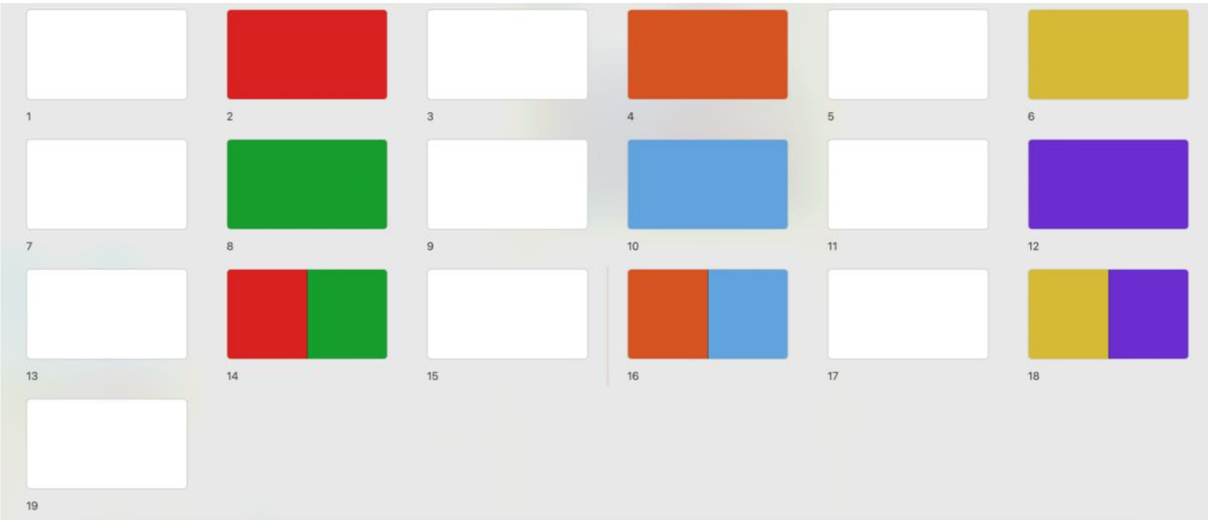
Example of congruent colour stimulus presentation



Note. The image shows a split-screen presentation used for congruent colour stimuli. Each half displays one colour from a complementary pair (in this case: yellow and purple), as presented to participants during the experiment.

Figure 3

Stimulus presentation sequence



Note. Overview of the structured sequence of stimulus presentations. Each slide was shown full-screen, alternating between colour stimuli and white screens to support neural reset before the next exposure.

By combining consistent RGB calibration with a fixed stimulus sequence, the visual material was both technically robust and experientially standardised. These design decisions allowed the study to focus clearly on the neural and affective effects of colour warmth and congruency in a fashion branding context.

Design instruments

The EEG setup will include a standard 32-channel cap that records electrical activity from brain regions associated with emotional processing (prefrontal cortex and amygdala). Stimuli will consist of digital images of fashion items displayed in warm (red, yellow, orange) and cool (blue, green, purple) colours, each presented in single contexts, such as a single dominant colour, and in mixed contexts, where two colours are visibly combined in a congruent manner to maintain harmony and alignment with the overall design.

Self-report measures were administered both before and after stimulus exposure. Self-report measures were administered both before and after stimulus exposure. The PANAS was used to measure emotional states such as positive affect (e.g., inspired, alert) and negative affect (e.g., distressed, upset), and was completed at four key time points: once at baseline (T0) and again following each stimulus condition (T1–T3). In addition to PANAS, for the additional research, a set of five custom Likert-scale items was developed to assess participants' aesthetic evaluations of congruent colour combinations. These items were inspired by prior literature on colour harmony and aesthetic preference (e.g., Reber et al., 2004; Luarn et al., 2024) and aimed to capture subjective perceptions of visual attractiveness, harmony, satisfaction, colour complementarity, and overall aesthetic pleasure. Items were phrased in clear, participant-friendly language and rated on a 5-point scale from "Not at all" to "Very much."

EEG data will be analyzed for spectral power, event-related potentials, and connectivity, focusing on alpha and beta wave activity to assess states of relaxation, arousal, and cognitive engagement. For the event-related potentials, the stimulus material required includes the sequential presentation of the designed fashion items. ERPs work by time-locking neural responses to specific stimuli, enabling the study of how the brain processes these visual inputs. Each image is presented for five seconds, followed by a neutral white slide to allow brain activity to return to baseline before the next stimulus. In general, ERP components such as the N100 and P200 are characterised by peaks in the range of 2–10 μV (Luck, 2014). A strong ERP response typically refers to a higher amplitude within this range, indicating increased neural engagement with the stimulus. Conversely, a reduced response involves a lower amplitude or flatter waveform. However, ERP amplitudes can vary substantially depending on factors such as electrode montage, referencing method, and preprocessing pipeline (e.g., filtering, baseline correction, artefact rejection). The ERP data is extracted by averaging EEG signals time-locked to the onset of each stimulus, isolating the brain's immediate response to the solid colours and congruent colour combinations of the fashion item, in this study that will be on a hoodie. This technique helps identify how these stimuli elicit brain activity related to attention, recognition, and emotional engagement.

Pre-test results

A pre-test was conducted with eight participants**,** evenly divided by gender, from the target research population to ensure the effectiveness of the experimental stimuli. This pre-test aimed to evaluate the visual presentation of the colours, including the solid colour stimuli, the dual presentations featuring congruent colour combinations, and their application in hoodies. Participants were asked to identify which colour they observed after being presented with the visual stimuli. Their responses confirmed that the chosen colour schemes were visually distinct and easily recognisable across all conditions, validating the stimuli for use in this study. Additionally, the pre-test ensured that the colours were consistent in their presentation, supporting the overall reliability of the experimental design.

Validity and reliability

To ensure the methodological credibility of this study, particular attention was paid to both validity and reliability throughout the research process. These quality indicators address whether the study accurately measured what it intended to measure (validity) and whether the results are consistent and replicable across time and conditions (reliability). The following sections outline how these principles were safeguarded in the design, instrumentation, data collection, and analysis phases.

Validity of measures and protocols

Validity is supported through the alignment of EEG frequency bands with emotional states identified in prior research, where beta activity is linked to arousal and attention, and alpha activity to relaxation (Elliot & Maier, 2014; Khadir et al., 2023). To ensure content validity across both subconscious and conscious levels, the study employed a multi-layered data collection protocol. EEG data were collected during stimulus exposure (T1), capturing immediate neural responses to the colour stimuli. Self-reported emotional responses were assessed at three points: before exposure (T0, baseline), directly after viewing each stimulus (T1), and following all exposures (T2, post-session reflection). This timeline allows for a robust comparison of neural activation with changes in conscious affect. The PANAS and Likert-scale questions are well-established measures for capturing self-reported emotions, ensuring content validity in measuring both subconscious (EEG) and conscious (self-reported) responses. The internal consistency of the self-report scales was evaluated using Cronbach's alpha. The positive affect subscale (6 items; excited/aroused, energised, trust, calm/relaxed, dependability, and serenity) showed acceptable reliability ($\alpha = 0.70$), while the negative affect subscale (4 items; overwhelmed, restless, confused, and discomfort) demonstrated good reliability ($\alpha = 0.77$). These values indicate that the PANAS measures used in this study were internally consistent and suitable for assessing emotional responses to colour stimuli.

The validity of the EEG data was further enhanced by ensuring optimal electrode impedance levels throughtout the data collection According to the EEG system guidelines used in this study, impedance was required to be kept within low thresholds to ensure that the recorded signals closely reflect actual brain activity rather than being distorted by resistance-related artefacts. This rigorous control over electrode-skin contact minimised potential confounding factors, such as signal distortions, and improved the precision of the neural measurements. Consequently, the data obtained provides a valid representation of participants' responses to the visual stimuli, aligning with the study's objectives to measure emotional engagement and cognitive processes. This careful management of electrode impedance ensured the accuracy of the neural responses being measured, aligning with the study's goal of investigating the effects of colour on emotional engagement and cognitive processing.

Additionally, the exclusion colour-blind participants (N = 2) ensured that the study captured accurate perceptions of the stimuli as designed, further supporting validity. Since the experiment focused on the neural and emotional effects of specific colour stimuli, this measure avoided confounding factors that could arise from variations in colour perception, ensuring that responses reflected the intended stimuli.

Reliability of measures

To ensure reliability, EEG data was collected under controlled conditions. To minimise noise and artefacts and enhance signal quality, impedance—representing the resistance between electrodes and the scalp—was consistently maintained at low levels ('green' or 'yellow' on the impedance monitor) across all participants.

Stimuli were presented in a fixed order across participants, with neutral white slides inserted between each stimulus to allow brain activity to return to baseline. This structured presentation sequence ensured comparability across conditions while reducing the risk of carryover effects.

Reliability in self-report data was supported by the use of established measures, as established before, PANAS and a custom Likert-scale questionnaire. The internal consistency of these instruments was verified through Cronbach's alpha, resulting in $\alpha = 0.70$ for the positive affect subscale and $\alpha = 0.77$ for the negative affect subscale, indicating solid internal reliability.

Finally, data reliability was reinforced through repeated measures within participants, allowing for consistency checks across conditions, including warm versus cool colours and solid versus congruent colour combinations.

These measures collectively ensured that the study's findings are robust and reproducible.

Data collection procedure

Data collection will involve the following steps:

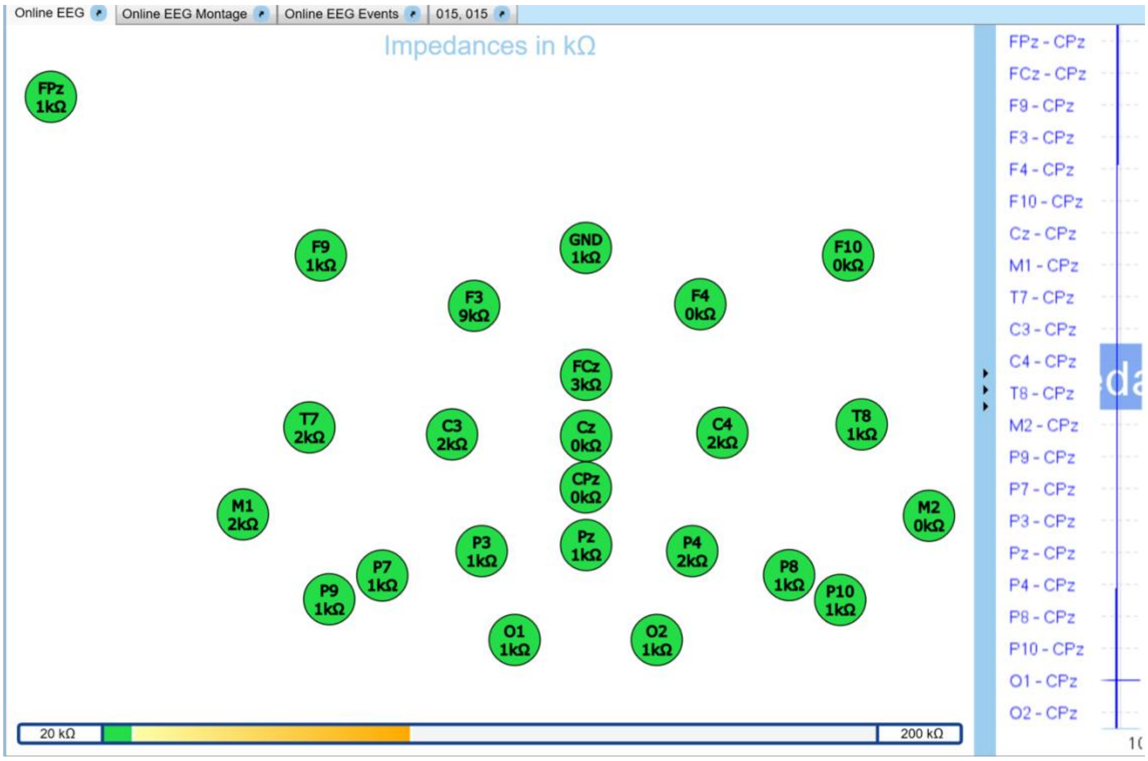
1. **Participant briefing and consent**: Participants will be informed of the study's purpose, procedures, and confidentiality assurances, and consent will be obtained.
2. **Visual presentation of the colours**: Before proceeding with EEG recordings, participants will undergo a brief colour vision test to screen for potential colour blindness. This ensures that all participants can accurately perceive the colour stimuli used in the study. Before the EEG recording session began, participants completed a brief colour vision screening to ensure accurate perception of the visual stimuli. This screening involved a PowerPoint slide displaying six solid colours (red, orange, yellow, green, blue, and purple), one at a time. Each participant was asked to verbally

identify the colour shown. Only participants who correctly named all six colours were included in the experiment.

3. **Electrode impedance measurement**: Prior to data collection, electrode impedance was measured, for each participant while wearing the ANT Neuro cap, to ensure high-quality signal acquisition. As shown in *Figure 4*, all electrodes were adjusted to reach impedance levels below 20 kΩ, indicated by green circles. Maintaining low impedance across all channels is essential to ensure optimal conductivity between the scalp and electrodes, thereby minimising noise and maximising signal clarity.

Figure 4

Electrode impedance check prior to EEG recording.



Note. Electrode impedances were measured with the EEG cap (waveguard™ by ANT Neuro) in place. Green circles indicate that all electrode impedances were below 20 kΩ, which was the required criterion level before recording could begin.

4. **Baseline EEG measurement**: A baseline EEG recording will be taken with participants in a relaxed state. An example of the raw data output (baseline versus stimuli) is provided in Appendix B.
5. **Pre-stimulus self-report measures**: Before viewing the stimuli, participants will complete initial self-report measures, including the PANAS and Likert-scale questions to assess their baseline emotional state, cognitive engagement, and associative meanings.
6. **Stimulus presentation**: Participants will view a total of 9 item stimuli, featuring warm colours (red, orange, yellow), cool colours (blue, green, purple), and three contrasting yet congruent colour combinations (red and green, orange and blue, yellow and purple). These stimuli will be presented on full screen, with all colours standardised to 75% saturation to ensure consistency. As previously described in the Materials section, each stimulus was presented for five seconds, followed by a five-second white screen to allow brain activity to return to baseline. This structure was maintained consistently throughout the measurement phases, and the presentation order remained consistent for all participants to ensure uniformity and comparability of responses.
7. **Post-stimulus self-report measures**: Immediately after viewing each set of images (T1–T3), participants completed PANAS and Likert-scale questions to report their emotional responses, cognitive engagement, and associative meanings. At T4, a final questionnaire assessed aesthetic responses to congruent colour combinations applied to hoodies, using five criteria: visual attractiveness, harmony, satisfaction, complementarity, and overall appeal. This structured sequence across five measurement phases (T0–T4) allowed for the systematic collection of both neural (ERP, PSD) and conscious (self-reported) responses, enabling meaningful

comparisons between colour conditions and stimulus contexts. An overview of the full measurement timeline is provided in Table 2. For additional procedural detail, see Appendix C.

Table 2

Overview of measurements collected

Time point	Phase	Measures collected
T0	Baseline (pre-stimulus)	Resting-state EEG (alpha/beta), PANAS, and baseline self-report
T1	Exposure to warm colours	EEG (ERP + PSD) during stimulus, PANAS + post-stimulus emotional response questionnaire
T2	Exposure to cool colours	EEG (ERP + PSD) during stimulus, PANAS + post-stimulus emotional response questionnaire
T3	Exposure to congruent colour combinations	EEG (ERP + PSD) during stimulus, PANAS + post-stimulus emotional response questionnaire
T4	Final post-experiment questionnaire	Likert-scale ratings on the congruent colour combinations applied to hoodies using five aesthetic criteria: visual attractiveness, harmony, satisfaction, complementarity, and overall appeal.

8. **Debriefing**: After data collection, which took approximately 45-60 minutes, participants will be debriefed, with an opportunity to ask questions and receive further context on the study's goals.

Data analysis plan

To test the hypotheses, a combination of EEG-based (ERP and PSD) and self-report analyses (PANAS and Likert-scales) was conducted. As all participants were exposed to each experimental condition, a within-subject (repeated measures) design was used throughout. The repeated measures ANOVA assesses whether there is a statistically significant effect of phase on spectral power (PSD) while controlling for individual differences between participants. An exception was made for the ERP analyses, which relied on paired-sample t-tests due to the nature of time-locked stimulus data. Additionally, data from the T4 questionnaire were analysed using a Welch two-sample t-test to compare conceptual constructs.

To assess neural dynamics, ERP amplitudes were analysed with paired-sample t-tests comparing components (N100, P200) across conditions T1–T3. Each ERP segment included a brief pre-stimulus window (–200 to 0 ms), which served as an internal baseline for amplitude calculation. This approach allows accurate intra-condition comparisons (e.g., pre-stimulus vs. onset) without referencing resting-state data.

In contrast, frequency-specific PSD values (alpha and beta bands) were analysed using repeated-measures ANOVA across all four timepoints (T0–T3), allowing detection of trends in arousal and relaxation over time. This analysis was performed separately for two brain regions: the prefrontal cortex and the amygdala. This approach was selected because the same participants contributed data across all phases, making it essential to account for within-subject variability. Similarly, self-reported emotional responses collected using the PANAS at T0 through T3 were assessed with repeated-measures ANOVA to evaluate shifts in emotional states across the stimulus conditions. If the repeated-measures ANOVA revealed significant effects for alpha or beta power, post hoc comparisons were planned using Bonferroni-corrected paired-sample t-tests between all combinations of phase pairs (T0–T3), since

ANOVA only indicates that a difference exists without specifying which phases differ. To correct for the increased risk of Type I error, also known as false positives, due to multiple comparisons, the Bonferroni correction was applied to the resulting p-values. Such analyses allow for examining frequency- and region-specific patterns potentially related to cognitive arousal and relaxation.

At T4, a separate questionnaire evaluated aesthetic responses to congruent colour combinations applied to hoodies. Likert-based scores (e.g., visual attractiveness, harmony, satisfaction) were analysed using a Welch two-sample t-test to assess conceptual differences between key evaluative dimensions (e.g., visual attractiveness versus aesthetic pleasant).

This multi-method approach enables a comprehensive evaluation of how colour stimuli affect both subconscious neural dynamics and consciously perceived emotional and aesthetic experiences—central to the aims of this study.

Hypothesis 1a

Warm colours led to heightened emotional arousal, reflected in increased beta wave activity compared to the resting-state baseline (T0), and enhanced ERP amplitudes relative to the internal pre-stimulus baseline.

- **ERP peaks (N100, P200):** Paired-sample t-test to compare neural responses between N100 and P200, when subjected to warm colour stimulus, measured in Python.
- **Beta power (13–30 Hz):** Repeated-measures ANOVA was used to assess changes in arousal-related brain activity, measured in Python.
- **PANAS scores:** Repeated-measures ANOVA was used to assess changes in self-reported positive and negative affect, measured in R.

Hypothesis 1b

Cool colours showed a relaxed emotional response, reflected in increased alpha wave activity compared to the resting-state baseline (T0), and reduced ERP amplitudes relative to the internal pre-stimulus baseline within each event-locked segment.

- **ERP peaks (N100, P200):** Paired-sample t-test to compare neural responses between N100 and P200, when subjected to cool colour stimulus, measured in Python.
- **Alpha power (8–13 Hz):** Repeated-measures ANOVA was used to assess relaxation-related brain activity, measured in Python.
- **PANAS scores:** Repeated-measures ANOVA was used to assess changes in self-reported positive and negative affect, measured in R.

Hypothesis 2

Congruent colour combinations (e.g., blue–orange) create a balanced emotional response through a mix of arousal and relaxation.

- **ERP peaks:** Paired-sample t-test to evaluate delayed N100 and enhanced P200 responses in the congruent condition, as congruent colour combinations are perceived as harmonious and pleasant, reducing early sensory alertness (N100) while enhancing emotional and evaluative processing (P200). The ERP peaks were measured in Python.
- **Alpha and beta power:** Repeated-measures ANOVA was used to detect a mixed pattern of relaxation and arousal, measured in Python.
- **PANAS scores:** Repeated-measures ANOVA was used to assess changes in self-reported positive and negative affect, measured in R.

Extra data regarding the application to clothing

Congruent colours applied to fashion: A Welch two sample t-test was used to compare mean scores between the two evaluative dimensions (visual attractiveness and aesthetic pleasing scores), which was measured in R. As both dimensions were rated by the same participants, the paired-sample test was appropriate to account for within-subject variability.

Analytical tools

EEG data (ERP and PSD) were analysed using Python due to its compatibility with EEG processing packages, whereas all questionnaire data, including PANAS and Likert-scale items, were processed and statistically analysed in R.

Results

Results overview and structure

This section presents the findings of the study, structured according to the four experimental phases: T0 (baseline), T1 (warm colours), T2 (cool colours), and T3 (congruent colours), with an additional questionnaire (T4). At each phase, a combination of EEG-derived and self-reported data was collected to evaluate the cognitive and emotional effects of colour exposure.

EEG data were analysed using both event-related potentials and power spectral density. ERP analysis focused on the N100 and P200 components, which are associated with early perceptual attention and emotional evaluation, respectively. PSD analysis examined alpha power (8–13 Hz), linked to relaxation, and beta power (13–30 Hz), linked to arousal.

ERP analysis

Event-Related Potential analysis was conducted to determine whether different colour conditions showed differential early attentional and emotional responses. The analysis focused on the N100 and P200 components, which are commonly used markers of stimulus processing. The N100 is typically associated with stimulus detection and early attentional allocation, whereas the P200 is linked to emotional and cognitive evaluation of stimuli as shown in *Figure 5*.

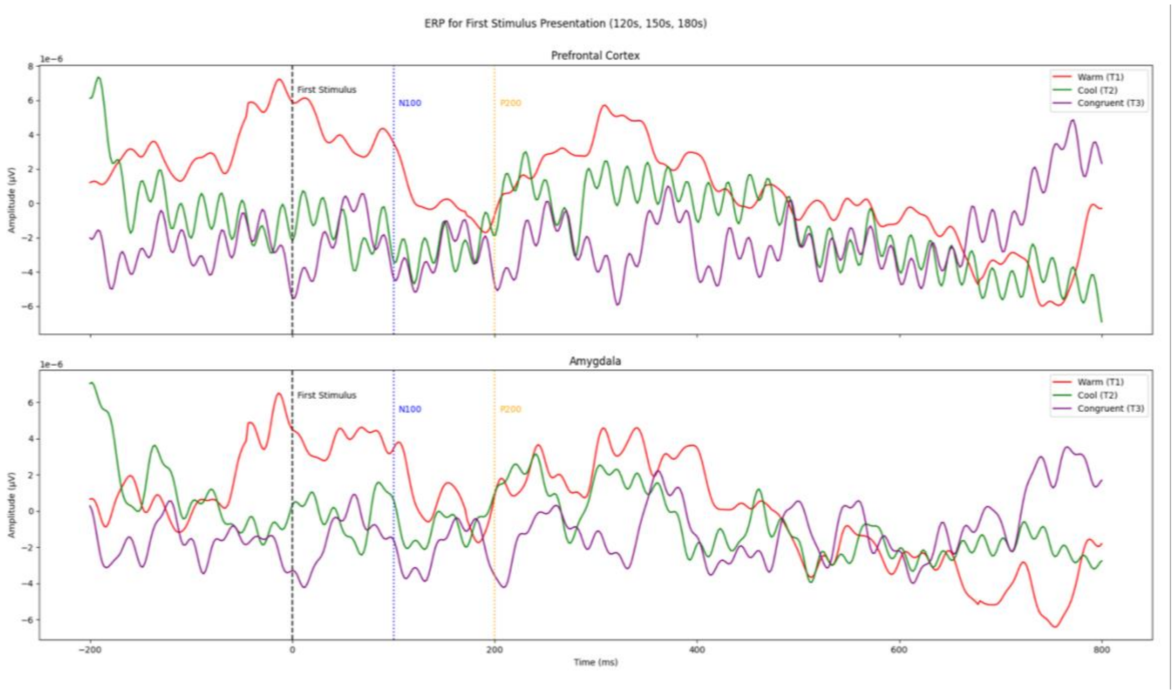
ERP amplitudes typically range from 2–10 µV (Luck, 2014), but lower amplitudes are not uncommon depending on signal quality, preprocessing, and task demands. In this study, relative differences were prioritised over absolute size. In this study, ERP amplitudes were notably lower than the conventional ~5 µV benchmark (Luck,2014). This could be due to several methodological aspects: the use of a relatively small number of stimulus repetitions per condition, a high-impedance EEG system, or individual differences in scalp conductivity. Moreover, the emotional and perceptual stimuli used in the study may evoke subtler responses than, for instance, auditory or motor stimuli. Therefore, while the absolute amplitudes are modest, relative differences between conditions remain meaningful, and were used for all statistical comparisons.

Furthermore, ERP responses to each colour condition were analysed independently and not statistically compared across conditions (e.g., T1 vs. T2 or T3), due to the within-subject design and limited statistical power. Instead, the analysis focused on whether the ERP components for each condition significantly differed from their own baseline—indicating whether a measurable neural response occurred at all.

The ERP analysis examined whether different colour conditions influenced early attentional and emotional processing, as indicated by the N100 and P200 components.

Figure 5

Event-Related Potential (ERP) for first stimulus presentation



Note. The figure illustrates ERP waveforms recorded from the prefrontal cortex (top) and amygdala (bottom) in response to warm (T1), cool (T2), and congruent colour stimuli (T3). The x-axis represents time (ms) relative to stimulus onset, while the y-axis indicates amplitude (μV). The vertical dashed line at 0 ms marks the stimulus presentation. The N100 component (blue dotted line) represents early attentional processing, while the P200 component (orange dotted line) reflects later emotional and cognitive evaluation. Different coloured lines indicate ERP responses to each condition.

Table 3

Statistical results for ERP components (N100 and P200) across brain regions and colour phases

Phase	Region	T-statistic	P-value	M N100 (μV)	M P200 (μV)
Warm (T1)	Prefrontal cortex	1.326	0.197	3×10^{-6}	-5x10^7
Warm (T1)	Amygdala	1.395	0.176	3×10^{-6}	2×10^{-7}
Cool (T2)	Prefrontal cortex	-0.828	0.416	-2×10^{-6}	-6×10^{-7}
Cool (T2)	Amygdala	-0.572	0.573	3×10^{-9}	8×10^{-7}
Congruent (T3)	Prefrontal cortex	0.185	0.855	-3×10^{-6}	-4×10^{-6}
Congruent (T3)	Amygdala	0.410	0.686	-2×10^{-6}	-3×10^{-6}

Note. This table presents the results of paired-sample t-tests conducted on N100 and P200 amplitudes recorded from the prefrontal cortex and amygdala across the three colour phases. P-values greater than 0.05 indicate non-significant differences from baseline.

ERP responses to warm colours (Hypothesis 1a)

Hypothesis 1a proposed that warm colours would lead to heightened emotional arousal, reflected in increased beta activity and enhanced ERP amplitudes following stimulus onset. Descriptively, ERP plots (*Figure 5*) show a pronounced N100 component in both the prefrontal cortex and amygdala, followed by a visible P200 peak—indicating early attentional and emotional engagement with warm colours.

Despite these visual trends, paired-sample t-tests revealed no significant deviation from baseline. In the prefrontal cortex, the result was $t(24) = 1.33$, $p = .197$, with a mean N100 amplitude of 3×10^{-6} µV and P200 of -5×10^{-7} µV. In the amygdala, $t(24) = 1.40$, $p = .176$, with N100 = 3×10^{-6} µV and P200 = 2×10^{-7} µV, as shown in *Table 3*. Thus, although warm colours elicited descriptive ERP responses in expected directions, the findings do not statistically support the hypothesis that warm colours significantly amplify early emotional or attentional brain activity.

ERP responses to cool colours (Hypothesis 1b)

Hypothesis 1b expected cool colours to induce relaxation, reflected in reduced ERP amplitudes. The ERP waveform for cool colours showed a dampened N100 response and a near-flat P200 component (*Figure 5*), suggesting lower attentional and emotional engagement compared to the warm colour condition.

This was not supported by paired-sample t-tests, which showed non-significant results: in the prefrontal cortex, $t(24) = -0.83$, $p = .416$, with a mean N100 amplitude of -2×10^{-6} µV and P200 of -6×10^{-7} µV; and in the amygdala, $t(24) = -0.57$, $p = .573$, with N100 = 3×10^{-9} µV and P200 = 8×10^{-7} µV, as shown in *Table 3*. These results do not provide evidence that cool colours significantly reduce emotional arousal at early neural stages.

ERP responses to congruent colours (Hypothesis 2)

Hypothesis 2 proposed that congruent colour combinations (e.g., blue–orange) would result in a balanced emotional response, reflected in ERP waveforms that combine elements of both arousal and relaxation. In *Figure 5*, the N100 response appeared slightly delayed, and the P200 peak more pronounced in the prefrontal cortex, possibly reflecting additional cognitive processing demands.

However, paired-sample t-tests again revealed no significant differences. In the prefrontal cortex, the result was $t(24) = 0.19$, $p = .855$, with a mean N100 amplitude of –

3×10^{-6} μV and P200 of -4×10^{-6} μV. In the amygdala, $t(24) = 0.41$, $p = .686$, with a mean N100 of -2×10^{-6} μV and P200 of -3×10^{-6} μV, as shown in *Table 3.* These results do not confirm the hypothesis that congruent colours produce a harmonised neural pattern in early ERP components.

Power Spectral Density (PSD) analysis

In addition to ERP analysis, changes in frequency-specific brain activity were examined through power spectral density analysis. PSD was calculated for two bands of interest: alpha (8–13 Hz), associated with relaxation and reduced emotional arousal, and beta (13–30 Hz), linked to arousal and attention. Results are visualised in *Figure 6* and *Figure 7*, and descriptive and inferential statistics are summarised in *Tables 4–7*.

Table 4

Descriptive statistics of PSD power in the prefrontal cortex

Region	**Prefrontal Cortex**							
Band	**Alpha**				**Beta**			
Phase	Baseline	Warm	Cool	Congruent	Baseline	Warm	Cool	Congruent
Mean	0.087	0.057	0.089	0.087	0.049	0.047	0.061	0.057
SD	0.065	0.050	0.050	0.056	0.037	0.028	0.032	0.026

Note. Table 4 presents the mean and standard deviation (SD) of normalized power for the alpha and beta bands in the prefrontal cortex across all stimulus phases.

Table 5

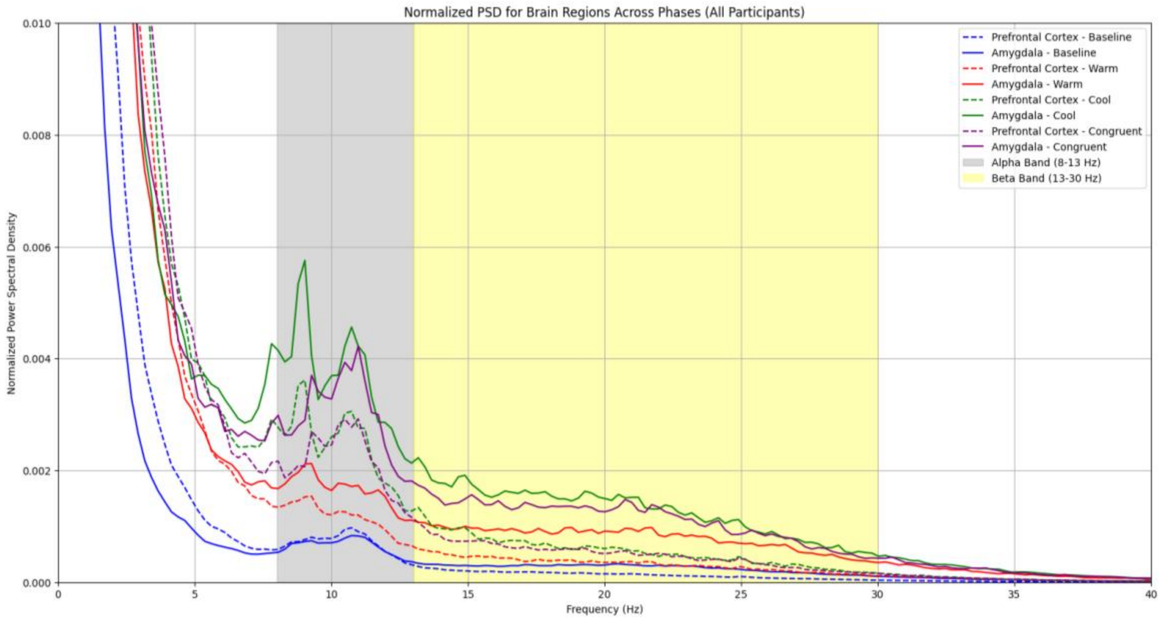
Descriptive statistics of PSD power in the amygdala

Region	**Amygdala**							
Band	**Alpha**				**Beta**			
Phase	Baseline	Warm	Cool	Congruent	Baseline	Warm	Cool	Congruent
Mean	0.122	0.081	0.132	0.125	0.108	0.095	0.119	0.110
SD	0.065	0.058	0.068	0.068	0.055	0.047	0.053	0.044

Note. Table 5 presents the mean and standard deviation (SD) of normalized power for the alpha and beta bands in the amygdala across all stimulus phases.

Figure 6

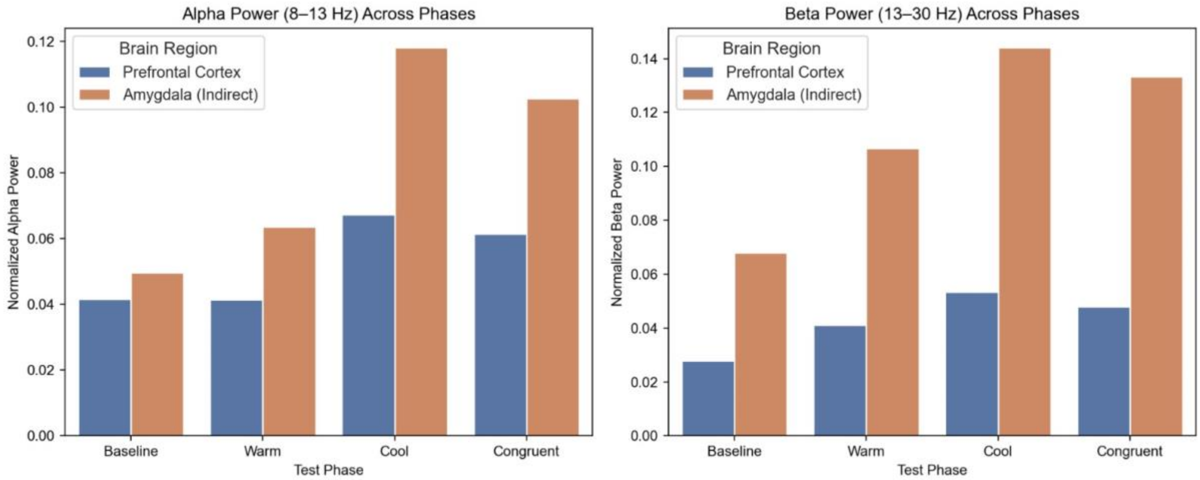
Power Spectral Density (PSD) analysis for brain regions across phases



Note. The figure displays the normalized power spectral density across different brain regions and conditions. The x-axis represents frequency (Hz), while the y-axis shows normalized power spectral density. The shaded areas indicate the alpha (8-13 Hz) and beta (13-30 Hz) frequency bands. Different line styles represent variations across conditions, including baseline, warm, cool, and congruent colour exposure.

Figure 7

Normalised alpha and beta power across test phases by brain region



Note. The left plot displays mean alpha power (8–13 Hz), and the right plot displays beta power (13–30 Hz) for each phase. Data are shown separately for the prefrontal cortex and amygdala. T0 = baseline, T1 = warm colours, T2 = cool colours, T3 = congruent colours.

Beta power (13-30 Hz) across conditions (Hypothesis 1a)

Hypothesis 1a predicted that warm colours would increase arousal, reflected in elevated beta power. Descriptively, *Figure 7* (right panel) shows a visual increase in beta power for warm colours, especially in the amygdala. However, pairwise comparisons using post-hoc paired-sample t-tests showed no significant differences between baseline and any of the colour conditions in either the prefrontal cortex or amygdala (all $p > .05$; see *Table 6* and *Table 7*). These results do not support the hypothesis that warm or congruent colours significantly increase arousal as measured by beta power. However, post-hoc paired-sample t-tests revealed that alpha power was significantly higher in the warm condition compared to baseline in both the prefrontal cortex ($p = .001$) and the amygdala ($p = .002$), indicating a clear neural response to warm colours.

Table 6

Overview of repeated measures ANOVA outcomes for alpha and beta power per brain region

	Frequency band	F-value	Num DF	Den DF	Pr > F
Prefrontal cortex	Alpha	10.929	3	72	5.347e-06
	Beta	1.453	3	72	.235
Amygdala	Alpha	9.233	3	72	3.0392e-05
	Beta	1.714	3	72	.172

Note. F-value indicates the test statistic from the ANOVA. Num DF = numerator degrees of freedom (between conditions); Den DF = denominator degrees of freedom (within participants); Pr > F = p-value indicating the significance of the phase effect.

Table 7

Post-hoc alpha power comparisons in the amygdala

Comparison	T-value	P-uncorrected	P-corrected
T0 – T1	4.258	<.001	.002
T0 – T2	2.652	.014	.084
T0 – T3	2.969	.007	.040
T1 – T2	3.087	.005	.030
T1 – T3	2.596	.016	.095
T2 – T3	-0.735	.470	1.000

Note. T0 = Baseline; T1 = Warm colours; T2 = Cool colours; T3 = Congruent colours. *P*-corrected values reflect Bonferroni-adjusted significance levels. The uncorrected p-value for the T0–T1 comparison was .000274, reported as <.001 for clarity.

Table 8

Post-hoc alpha power comparisons in the prefrontal cortex

Comparison	T-value	P-uncorrected	P-corrected
T0 – T1	4.327	<.001	.001
T0 – T2	2.609	.015	.092
T0 – T3	3.207	.004	.023
T1 – T2	3.461	.002	.012
T1 – T3	3.316	.003	.017
T2 – T3	-0.478	.637	1.000

Note. T0 = Baseline; T1 = Warm colours; T2 = Cool colours; T3 = Congruent colours. *P*-corrected values reflect Bonferroni-adjusted significance levels. The uncorrected p-value for the T0–T1 comparison was .000230, reported as <.001 for clarity.

Alpha power (8-13 Hz) across conditions (Hypothesis 1b)

Hypothesis 1b proposed that cool colours would enhance alpha power, reflecting increased relaxation. As shown in Figure 7 (left panel), alpha power appeared descriptively higher for cool colours, particularly in the amygdala. However, post-hoc comparisons following a significant repeated measures ANOVA did not reveal significant differences between the cool condition and baseline in either the prefrontal cortex (p = .092) or the amygdala (p = .084; see Tables 6 and 7). Thus, this hypothesis was not supported.

Alpha power response to warm colours

In contrast to the findings for cool and congruent colours, exposure to warm colours resulted in a statistically significant increase in alpha power in both the prefrontal cortex and amygdala. Post-hoc comparisons showed that alpha power was significantly higher in the warm condition compared to baseline, with $t = 4.327, p = .001$ in the prefrontal cortex and t

$= 4.258, p = .002$ in the amygdala (see Tables 7 and 8). These results indicate that warm colours show a measurable neural response, suggestive of changes in both cognitive and emotional processing.

Alpha and beta power response to congruent colours (Hypothesis 2)

Congruent colour combinations were hypothesised to evoke a balanced emotional response, potentially reflected in intermediate levels of alpha and beta power. However, repeated measures ANOVA revealed no significant differences in beta power when comparing the congruent condition (T3) to baseline (T0) in both the prefrontal cortex and amygdala, with $p = .235$ and $p = .172$, respectively (see Table 6). In contrast, alpha power comparisons indicated a significant increase from baseline in both regions: $p = .023$ in the prefrontal cortex and $p = .040$ in the amygdala (see Tables 6–8).

These findings suggest that congruent colour exposure did not show a neural response consistent with a distinctly balanced or harmonious emotional state. Instead, the observed increase in alpha power may reflect lowered arousal, though this pattern was not supported in the beta range. Thus, while not fully supporting hypothesis 2, the neural response to congruent colours may reflect a partially harmonised emotional state rather than a clearly distinct one.

PANAS

To assess participants' subjective emotional responses, self-reported data was collected using the PANAS. The analysis examined how exposure to different colour conditions influenced emotional affect, with a particular focus on positive and negative emotions across baseline, warm, cool, and congruent phases. Descriptive statistics are summarised in *Table 9*.

Table 9

Descriptive statistics for Positive and Negative Affect Scores (PANAS)

Condition	**Positive affect**		**Negative affect**	
	M	***SD***	***M***	***SD***
Baseline	3.49	0.64	1.91	0.80
Warm	3.48	0.77	1.81	0.85
Cool	3.65	0.57	1.48	0.56
Congruent	3.51	0.60	1.70	0.65

Warm colours and emotion

It was hypothesised that warm colours would increase positive affect and evoke heightened arousal. However, the results did not support this prediction. Positive affect in the warm condition (M = 3.48, SD = 0.77) was nearly identical to baseline (M = 3.49, SD = 0.64), and a repeated-measures ANOVA revealed no significant effect of condition on positive affect, $F(3, 69) = 1.63$, $p = .191$. Similarly, negative affect decreased slightly in the warm condition (M = 1.81, SD = 0.85) compared to baseline (M = 1.91, SD = 0.80), but this difference did not reach statistical significance in the overall ANOVA. These findings suggest that warm colours did not significantly elevate emotional excitement and may have introduced a subtle emotional discomfort for some participants, as reflected in the descriptive increase in negative affect.

Cool colours and relaxation

The second hypothesis stated that cool colours would enhance relaxation by reducing negative emotions. Results partially supported this hypothesis. Negative affect was significantly lower in the cool condition (M = 1.48, SD = 0.56) compared to both baseline ($p < .001$) and congruent ($p = .041$), as indicated by post-hoc comparisons following a significant ANOVA result, $F(3, 69) = 6.33$, $p < .001$. Positive affect in the cool condition ($M = 3.65$, $SD = 0.57$) was descriptively higher than in other conditions, but this difference was not statistically significant. These findings suggest that cool colours may have contributed to a more relaxed emotional state by reducing negative affect. However, the absence of a significant increase in positive affect implies that this effect was primarily driven by a reduction in discomfort, rather than by an increase in emotional excitement.

Congruent colours and emotional balance

It It was anticipated that congruent colour combinations would produce a balanced emotional response. A repeated measures ANOVA revealed a significant main effect of condition on negative affect, $F(3, 69) = 6.33$, $p < .001$. Positive affect in the congruent condition ($M = 3.51$, $SD = 0.60$) did not significantly differ from baseline, and negative affect ($M = 1.70$, $SD = 0.65$) was significantly higher than in the cool condition ($p = .041$), though not significantly different from baseline. These findings suggest that congruent colour combinations did not produce the anticipated emotional balance. Although negative affect was significantly lower compared to baseline, the absence of increased positive affect may indicate that the opposing colour pairs introduced subtle perceptual tension, rather than promoting emotional balance.

Additional analysis: the effect of congruent colours in fashion

To extend the theoretical findings into a practical context, additional self-report items were analysed to explore how participants perceived congruent colour combinations when applied to hoodies. This part of the study aimed to assess subjective impressions of colour congruency in fashion-oriented aesthetic design using five separate items: visual attractiveness, aesthetic pleasing, satisfaction, harmoniousness, and complementarity. Each aspect was rated on a five-point Likert scale (1 = Not at all, 5 = Very much), and analysed as a single item rather than a composite scale.

Descriptive statistics revealed that visual attractiveness received the highest mean score (*M* = 3.92, *SD* = 0.74), suggesting that participants generally found the colour combinations visually engaging and attention-grabbing. However, the relatively lower rating for aesthetic pleasing (*M* = 2.68, *SD* = 1.03) indicates that these combinations were not necessarily perceived as beautiful or harmonious. This contrast highlights an important distinction between visual impact and aesthetic balance. It suggests that although congruent (but contrasting) colours can produce strong visual appeal, they may not align with traditional notions of aesthetic harmony.

The other three items followed a similar trend. Satisfaction with the combinations was rated at *M* = 3.10 (*SD* = 0.97), harmoniousness at *M* = 2.80 (*SD* = 1.04), and complementarity at *M* = 3.20 (*SD* = 0.99). These findings imply that participants saw the colours as moderately compatible, but not strongly indicative of visual balance. The relatively lower mean for harmoniousness in particular suggests that some participants may have experienced these combinations as somewhat incongruent or visually overstimulating. This interpretation aligns with prior research indicating that even technically congruent or complementary colours can, in certain contexts, evoke visual complexity rather than a sense of aesthetic coherence.

Discussion

The primary objective of this study was to examine how neural and self-reported emotional responses are influenced by exposure to warm, cool, and congruent colour stimuli. By employing EEG measurements, including event-related potential components (N100 and P200) and power spectral density across the alpha and beta frequency bands, alongside self-reported affect ratings using the Positive and Negative Affect Schedule (PANAS), this research aimed to provide insights into the neural and emotional mechanisms underlying colour perception. The study further investigated whether these neural patterns align with self-reported emotional experiences, contributing to a broader understanding of how colour affects cognition and emotion.

The central research question guiding this study was: To what extent do colour warmth (warm versus cool) and congruent colour combinations in fashion design influence neural responses (e.g., alpha and beta wave activity) and emotional engagement, as measured through EEG?

This chapter discusses the main findings in relation to this question, along with theoretical and practical implications, limitations of the study, directions for future research, and a final conclusion.

Neural responses to colour conditions

One of the most notable findings is that warm colours significantly increased alpha power in both the prefrontal cortex and amygdala. Alpha activity is commonly associated with reduced arousal and a more relaxed cognitive state. This suggests that warm colours—despite their conventional link to stimulation and arousal—may also evoke relaxation-related neural responses in certain contexts. This finding contrasts with the original assumption that warm colours would primarily increase beta activity and emotional arousal. The fact that this significant increase in alpha power was not observed for cool or congruent colours highlights a unique neural profile for warm colour exposure. The similar pattern across both brain regions supports the interpretation that warm colours influence both cognitive and emotional processing. Interestingly, no significant changes were found in beta power. This could be due to the passive nature of the task, which may not have been sufficiently arousing to elicit the heightened beta activity typically associated with increased emotional engagement. This interpretation aligns with prior findings that warm colours tend to attract attention and evoke strong emotional responses (Elliot & Maier, 2014; Suk & Irtel, 2009), even if the context does not fully support arousal-driven neural activation.

For cool colours, no significant differences were found in alpha or beta power when compared to the baseline condition. This contradicts the hypothesis that cool colours would induce relaxation, as reflected in increased alpha activity. Although a slight descriptive increase in alpha power was observed, it was not statistically significant. Compared to warm colours—where alpha power increased significantly—cool colours showed a much weaker neural response. This suggests that the relaxing effect often attributed to cool tones did not reliably emerge in this context. These findings align partially with previous research by Küller and Mikellides (1993), who reported that while cool colours are generally associated with calming effects, their physiological impact can vary depending on situational and contextual factors. In the current study, the artificial nature of the colour presentation—shown on a screen rather than in a real-world environment—may have limited the emotional resonance typically associated with cool tones.

Congruent colours, such as blue–orange combinations, were hypothesised to show a balanced response between arousal and relaxation. However, no significant differences were found in alpha or beta power compared to baseline. This could indicate that contrasting yet complementary colours do not necessarily create a unique emotional balance but instead engage cognitive processing differently, as reflected in the ERP results. Rather than promoting harmony, these combinations may have increased cognitive complexity, possibly leading to a reduced sense of visual balance. This interpretation is further supported by the self-report data, which showed relatively low scores on harmony and aesthetic pleasing. Although participants rated the combinations as visually attractive, they were not consistently experienced as harmonious or satisfying. These findings suggest that congruent colours, while technically coordinated, may not have evoked the anticipated harmonised emotional state in this artificial presentation context. This aligns with previous research indicating that complementary colours can be experienced as less emotionally balanced depending on how they are perceived (Luarn et al., 2024; Martynenko et al., 2023).

Self-reported emotional responses

The self-reported data revealed both expected and unexpected patterns in how participants emotionally responded to colour stimuli. Warm colours did not significantly increase positive affect but were descriptively linked to a slight reduction in negative affect. Although this change was not statistically significant, it may suggest that warm tones contributed to mild emotional tension rather than excitement, possibly due to their stimulating yet context-dependent nature (Labrecque & Milne, 2011). This interpretation also aligns with the EEG findings, where warm colours produced a significant increase in alpha power—typically associated with cognitive disengagement, which may reflect internalised cognitive processing or decreased sensory attention to external stimuli, or internalised processing—rather than beta power, which would indicate heightened arousal.

According to PANAS data, cool colours, contrary to expectations, resulted in a non-significant increase in positive affect and a significant decrease in negative affect. This dual pattern suggests that rather than facilitating relaxation, cool tones may have elicited a sense of emotional disengagement or detachment. This challenges earlier research portraying blue tones as inherently calming (Elliot & Maier, 2014), and further reinforces that context, individual differences, and design application play key roles in shaping emotional responses to colour (Küller & Mikellides, 1993).

For congruent colour combinations, no significant change in positive affect was observed, but negative affect increased slightly, reaching statistical significance. This suggests that these technically harmonious colour pairings may not have been emotionally soothing for participants. Instead, participants may have experienced perceptual or visual complexity when processing these combinations—consistent with the relatively low ratings for harmony in the aesthetic questionnaire. This aligns with previous findings that complementary colours, while visually impactful, do not always result in emotional coherence and may introduce complexity in interpretation (Martynenko et al., 2023; Luarn et al., 2024).

Theoretical implications

The findings contribute to existing literature on colour perception and emotion by providing neural evidence that warm colours influence early attentional and emotional processing. The significant increase in alpha power for warm colours challenges the assumption that they solely enhance arousal, suggesting they may also modulate cognitive states such as internal focus or disengagement from external stimuli. This aligns with prior research on colour priming and neural engagement in branding contexts (Trimble, 2018). Interestingly, this neural relaxation response contrasts with the descriptive increase in self-reported negative affect, suggesting a possible mismatch between physiological and subjective emotional responses.

Contrary to expectations, cool colours did not significantly increase alpha power. Instead, they were associated with a significant decrease in negative affect, while positive affect showed a non-significant increase as shown in the PANAS results. This suggests that their calming effect may stem from a reduction in discomfort, rather than a boost in emotional excitement and that their relaxation effects may not be as universal as previously assumed.

Furthermore that context—such as task demands or visual composition—can influence emotional perception (Labrecque, 2020). The lack of significant neural changes despite a strong subjective emotional response also underscores the complexity of interpreting colour effects across methods.

The results further suggest that congruent colour combinations do not necessarily lead to an emotional balance but may instead require more cognitive effort to process. While not reflected in neural measures (ERP and PSD), the relatively low scores for harmoniousness and aesthetic pleasing indicate that participants did not perceive these combinations as emotionally balanced. This supports research on colour harmony, suggesting that technically complementary colours may increase perceptual complexity rather than induce aesthetic coherence (Luarn et al., 2024; Martynenko et al., 2023). This discrepancy between theoretical assumptions of harmony and the actual perception of congruent colour pairs highlights a deeper conceptual issue: harmony may not always be experienced affectively, even if it exists in design principles. From a theoretical perspective, this finding challenges the idea that visual balance automatically translates to emotional balance, and calls for a more nuanced understanding of how formal colour relationships interact with individual emotional processing.

Practical implications

From a fashion perspective, these findings have implications for clothing design and consumer behaviour. The strong attentional and emotional response to warm colours suggests they can be strategically utilised in fashion collections aimed at energising or stimulating the wearer. Warm tones may be particularly effective in activewear, promotional apparel, or statement pieces designed to capture attention (Elliot & Maier, 2014).

Conversely, the results suggest that merely using cool colours in clothing may not be sufficient to induce a sense of relaxation. Although traditionally associated with calmness, the self-reported data indicated a decrease in negative affect, while positive affect remained statistically unchanged despite a slight descriptive increase. This suggests that additional design elements, such as fabric texture, fit, or environmental lighting, may be necessary to reinforce the intended calming effect of cool tones (Singh et al., 2024).

Similarly, the findings on congruent colours suggest that combining contrasting colours in fashion does not necessarily produce an emotionally balanced effect but may increase visual complexity. This insight is relevant for fashion designers looking to create bold or trendsetting pieces that challenge conventional perceptions of harmony. Rather than evoking balance, congruent colour pairings might be more effective in stimulating intrigue or artistic expression.

Limitations and future research

While this study offers valuable insights into colour–emotion associations, several methodological limitations should be acknowledged—each of which provides meaningful directions for future research.

First, the stimuli were presented in a fixed order (warm, cool, congruent), which may have introduced order effects. Although neutral white slides were used to reset brain activity between trials, it remains possible that earlier stimuli influenced responses to later ones. To improve internal validity, future studies should implement a fully randomised presentation sequence to better isolate condition-specific effects and reduce sequential bias.

Second, although participants viewed each colour stimulus for five seconds, ERP activity is typically captured within the first 100–200 milliseconds post-stimulus onset. This prolonged exposure may have engaged later-stage cognitive and evaluative processes, diluting the sensitivity to early emotional responses. Future research should consider using shorter, time-locked exposure intervals to more precisely isolate early attentional and emotional components of neural activity.

Third, baseline recordings were initiated through manual pausing, resulting in minor inconsistencies in timing across participants. This procedure was based on the practical guidelines provided by the BMS lab, yet it limited the temporal precision of ERP analysis. Future studies would benefit from integrating an automated baseline interval directly into the stimulus presentation. This would standardise the process across participants and enhance the reliability of neural measures, particularly in studies where millisecond timing is critical.

Fourth, in the congruent colour condition, warm colours were consistently presented on the left and cool colours on the right. This layout mirrors typical left-to-right reading patterns in Western cultures and may have influenced visual attention. As Smith and Elias (2013) noted, observers often allocate more attention to the left side of an image. Consequently, warm tones may have been disproportionately attended to. Future research should counterbalance colour placement across trials to investigate whether positioning interacts with emotional perception or neural processing of colour combinations.

Finally, the current participant sample consisted exclusively of individuals under 30, representing a digitally native demographic accustomed to saturated, fast-changing media environments. This may have reduced the emotional impact of colour stimuli due to habituation or shifting aesthetic expectations (Georgiadou et al., 2024). Future studies should explore intergenerational differences in colour sensitivity by including a broader age range, comparing responses between digitally immersed and less digitally adapted populations.

Beyond these methodological considerations, future research may also benefit from incorporating more ecologically valid stimuli—such as real-life fashion imagery or motion-based presentations—rather than isolated digital colours. Such approaches would enhance the generalisability of the findings and provide a more realistic context for studying colour perception and emotional response.

Together, these methodological considerations and further examining generational shifts in colour perception, future studies can provide a more comprehensive perspective on how exposure to digital environments may be reshaping emotional responses to colour.

Conclusion

This research investigated how colour perception influences emotional and cognitive responses, with a particular focus on warm, cool, and congruent colour stimuli. The findings suggest that traditional assumptions about colour-emotion associations may not fully apply to younger individuals, particularly those under 25, who have grown up in a digital landscape saturated with dynamic and highly saturated colours. While warm colours have been historically linked to heightened arousal, the results of this study did not show a significant increase in positive emotional engagement, challenging prior literature. Instead, warm colours showed a significant effect on alpha power, indicating a more complex role in cognitive and emotional processing rather than a simple arousal-inducing effect.

Furthermore, cool colours, which have been theorised to induce relaxation, were associated with a significant decrease in negative affect and a non-significant increase in positive affect in self-reported data, while no significant changes were observed in EEG measures. This suggests that their calming effect may stem more from a reduction in discomfort than from enhanced emotional engagement. Similarly, congruent colour combinations, rather than providing a balanced emotional response, were associated with increased perceptions of visual complexity, potentially contributing to cognitive load rather than harmony. These findings indicate that colour perception is shaped by multiple factors, including generational influences and the broader visual environment in which individuals are immersed.

The results also highlight the importance of methodological considerations in colour research. Factors such as stimulus exposure duration, presentation order, and spatial arrangement of colours may influence participant responses. Additionally, the limitations related to timing accuracy in neural measurements suggest that future studies should refine experimental protocols to improve precision.

Overall, this research contributes to a deeper understanding of how colour perception influences emotional processing. It underscores the need for further investigation into generational shifts in colour processing and the role of digital exposure in shaping emotional responses to colour. Although these questions remain open, the present findings offer a valuable foundation for future exploration and invite designers, researchers, and marketers to rethink colour as a powerful emotional tool in both fashion and visual branding.

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Appendix

Appendix A

Statement about the use of AI

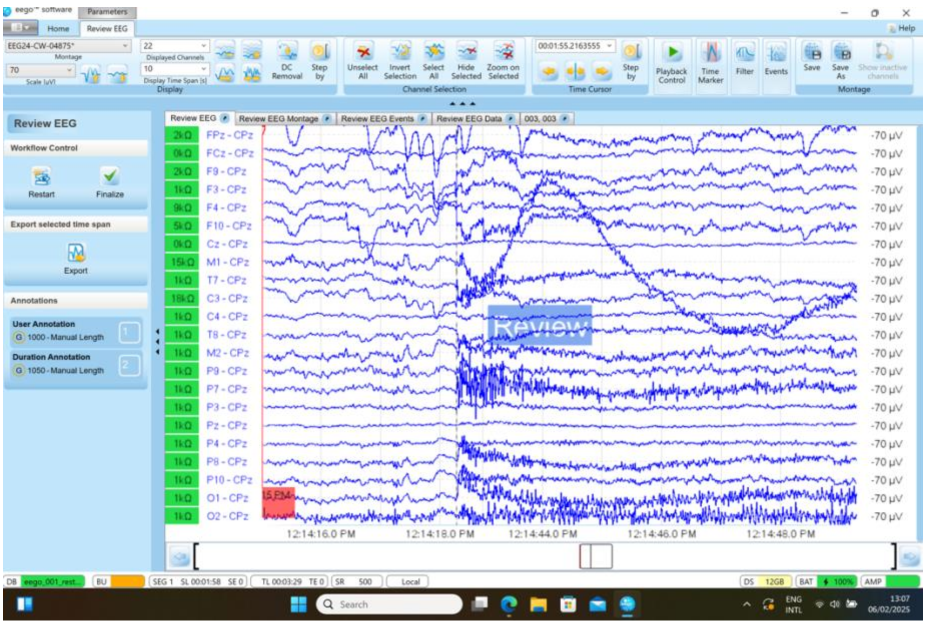
During the development of this thesis, the researcher used ChatGPT to help improve the clarity and strength of some sentences, ensuring that the ideas were communicated in a more structured and comprehensible way.

Additionally, ChatGPT was consulted for technical support in coding tasks using R, such as script structuring, troubleshooting, and visualising statistical results. All analytical decisions and interpretations were made independently by the researcher.

Appendix B

Figure 8

Raw data output EEG recording



Note. Baseline EEG activity is shown on the left, while stimulus-related brain activity appears on the right side of the recording.

Appendix C

Extended measurement protocol

The measurement timeline summarises the multi-phase structure already outlined above, consolidating EEG and self-report measures across five distinct timepoints (T0–T4). These phases were designed to capture both subconscious (neural) and conscious (self-reported) responses to warm, cool, and congruent colour stimuli, using a fixed sequence to ensure comparability between participants.

At T0 (baseline), a two-minute resting-state EEG recording was conducted, followed by the completion of self-report measures, including PANAS and Likert-scale items to assess participants' emotional and aesthetic states. During T1 to T3, participants were exposed to different types of colour stimuli: warm, cool, and congruent combinations. EEG activity was recorded continuously during these phases, including both event-related potentials and power spectral density data. Each stimulus was displayed for five seconds and followed by a neutral white slide of equal duration to allow the brain to reset between exposures. After each condition, participants completed PANAS and supplementary self-report items.

At T4, participants evaluated the same colour combinations in an applied fashion context, specifically hoodies, using a separate set of Likert-based items that measured visual attractiveness, harmony, satisfaction, and complementarity. This final stage enabled the comparison of responses to abstract colour stimuli versus contextually embedded fashion items.