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Colored halos around faces and emotion-evoked colors: A new form of synesthesia

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Abstract

The claim that some individuals see colored halos or auras around faces has long been part of popular folklore. Here we report on a 23-year-old man (subject TK) diagnosed with Asperger's disorder, who began to consistently experience colors around individuals at the age of 10. TK's colors are based on the individual's identity and emotional connotation. We interpret these experiences as a form of synesthesia, and confirm their authenticity through a target detection paradigm. Additionally, we investigate TK's claim that emotions evoke highly specific colors, allowing him, despite his Asperger's, to introspect on emotions and recognize them in others.

Keywords

Synaesthesia; Color; Fusiform; ffa; Qualia

In the nineteenth century, Francis Galton observed that a certain proportion of the general population who were otherwise normal had a condition he dubbed 'synesthesia'; a sensory stimulus presented through one modality spontaneously evoked a sensation in an unrelated modality (Galton, 1883). For example, an individual may experience a specific color for every given note, or every grapheme (printed number or letter) may be tinged with a specific hue (e.g., C-sharp or the number 5 evoking red). Although synesthetic experiences were long disregarded as a rare curiosity, there has been a tremendous resurgence of interest in the last decade (e.g., Mattingley, Rich, Yelland, & Bradshaw, 2001; Ramachandran & Hubbard, 2001a, 2003). Furthermore, this research has demonstrated that the phenomenon is relatively common (2–4% of the population; Simner et al., 2006), is mediated by genetic factors (Asher et al., 2009), and can influence aspects of everyday life ranging from memory (Smilek, Dixon, Cudahy, & Merikle, 2002) to creativity (Ward, Thompson-Lake, Ely, & Kaminski, 2008).

Several lines of evidence suggest that in most instances of synesthesia, the evoked color is a sensory experience as opposed to a high-level memory association (e.g., from having used colored refrigerator magnets as a child). Synesthetically induced colors can lead to perceptual segregation (Ramachandran & Hubbard, 2001a; Ward, Jonas, Dienes, & Seth, 2010), different portions of a single letter can have multiple colors (Ramachandran & Brang, 2010), and some color anomalous synesthetes may even see synesthetic colors that are unique from those experienced in the real world (Martian colors; Ramachandran & Hubbard, 2001b), despite the absence of the 'necessary' cone pigments. Furthermore, synesthetically

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induced colors can drive apparent motion (Kim, Blake, & Palmeri, 2006; Ramachandran & Azoulai, 2006) and the vividness of synesthetic colors can vary with eccentricity and field laterality (Brang & Ramachandran, 2009). Taken collectively, these observations support the early sensory cross-activation theory of synesthesia, although these do not negate powerful top-down influences (demonstrated using Navon figures; Ramachandran & Hubbard, 2001b) and the existence of higher forms of synesthesia that are more 'conceptually driven' and harder to relate to physiology.

Research into the neural basis of synesthesia has further confirmed the sensory cross-activation theory of many robust forms of synesthesia. For example, simple achromatic graphemes will spontaneously and inevitably activate grapheme-regions in the fusiform gyrus in tandem with area V4 (Brang et al., 2010; Hubbard, Arman, Ramachandran, & Boynton, 2005; Sperling et al., 2006). Furthermore, the cross-activation of these sensory regions is mediated by increased white-matter connectivity in synesthetes, as assessed by diffusion tensor imaging (Rouw & Scholte, 2007). Given that the fusiform gyrus has clusters of cells responsive to faces in addition to colors and graphemes, one might predict the existence of 'face-color' synesthesia in some individuals. Further, such incidences of which may explain the occasional reports of colored halos around individuals – a phenomenon that is usually relegated to the domain of fringe psychology. We had searched for such synesthetes over a decade ago, to no avail, but recently came across one by accident.

CASE REPORT

TK is a 23-year-old male who had been clinically diagnosed with Asperger's syndrome. According to TK, when he was younger he found it impossible to understand facial expressions and emotions, whether his own or those of others, and thus found it difficult to interact socially. Around the age of 10 his mother suggested that he attempt to label the feeling of each emotion (presumably based on context, social situation, and facial expressions) with a specific color, in an attempt to relay the appropriate emotions to his father and her. For example, while experiencing what he considered happiness he would tell his parents that he was feeling 'green'. It is unclear whether there were pre-existing emotion–color biases which were subsequently encouraged by his parents or whether they were arbitrarily imposed in early life by his parents to infuse in him some semblance of an emotional life. In either case, he reports that this strategy helped immensely. Further, by comparing the color elicited by another person with the emotion that would be associated with the same color in his own mind, TK was able to 'read' the other individuals' emotions more accurately.

At about the same time that he began associating colors with emotions (Experiment 2), he also began seeing colored halos around individuals (Experiment 1). The color of these halos corresponds to TK's emotional stance toward that particular person, and when a new individual is encountered a blue halo emerges *de-nouveau* and the color evolves progressively with repeated exposure. TK claims that the halos are clearly 'seen' or perceived around the person's face and body and not merely imagined (although such words lose their resolving power when dealing with such ineffable experiences as synesthesia).

EXPERIMENT 1: TK'S HALOS

During our initial interview, TK was accompanied by a female companion who he had known for several years. We instructed him to look at this individual standing in front of a blank white screen and TK noted that he perceived a bright red halo radiating approximately 4 to 6 visual degrees from her body. We then drew an outline on the screen surrounding his companion (see Figure 1). TK noted with surprise that the colored halo became more intense, spread out from the body, and was blocked precisely and crisply at the outline; behaving in this regard like some sensory color illusions such as ‘neon spreading’ (Nakayama, Shimojo, & Ramachandran, 1990). When we made a small gap in the outline TK exclaimed that the color ‘leaked out’ through the opening by a few inches. By drawing the outline selectively around the face, arms, or torso we were able to show that the color evoked was especially pronounced around the face and less so around other body parts. This fits the physiological observation (Downing, Jiang, Shuman, & Kanwisher, 2001) that although the fusiform gyrus also has cells for arms, they are sparser than those tuned to faces.

After TK made the observation that a border drawn around a subject ‘traps’ his halos, we performed some informal tests to determine the validity of his statement. We asked TK to look at the student’s face while we surreptitiously introduced a large vivid red spot near the student’s ear (approximately 2 degrees visual angle). The spot served as a vivid cue against the white background, being immediately noticed and attended to by the other researchers in the room. TK did not notice any change. Yet when we repeated the procedure with a green spot, TK spontaneously attended to the spot as expected, and queried us about it. After presenting the red spot a second time after delay, he again failed to notice it was there. It was only after TK was told that a spot was present and asked to identify its location that TK located it after several seconds of searching. The same pattern of results were not seen when a spot, red or green was introduced to a location outside of the border. Under these circumstances, TK spontaneously attended to them. This formed the basis for a formal reaction time experiment to give objective verification that TK does indeed experience halos.

Methods

A 1.6-m tall female undergraduate (who had a blue halo) stood 15 cm away from the white sheet. The previously described images were back-projected onto the white sheet around the body of the female undergraduate (Figure 1). Each participant stood 1.5 m away from the sheet as a single grapheme was projected at a random location either inside or outside of the border. An early localizer task using black dots determined that each grapheme location was clearly visible by each subject, and TK indicated that his halo was trapped at each location along the border. Each subject was instructed to indicate whether the present grapheme was either an ‘A’ or an ‘M’, and did so by speaking into a microphone (accuracy recorded for offline processing and voice onset response times recorded by EPrime Serial Response Box). Each grapheme was presented without time limit, although subjects were told to respond as quickly and accurately as possible. Each response was followed by a 2250-ms break where only the border was present. A beep indicated the beginning of each trial and let the subject know to begin looking for the grapheme. There were five blocks; each containing 32 trials with randomly assigned graphemes and locations for a total of 160 trials for the whole experiment (40 for each grapheme; blue A, blue M, orange A, orange M). For each colored grapheme there were 20 images per side (e.g., left), 10 of which were located inside of the border. Each grapheme subtended 1.5 degrees visual angle vertically, and was a minimum of 3 degrees visual angle from the student’s body. Three-minute breaks were given between each block.

Apparatus

A projector (Proxima Desktop Projetor 9260; Proxima Corp., San Diego, CA) was used to backlight a 1.76×2.26-m white sheet. The projector was 0.77 m off the ground and 3.43 m behind the white sheet. The projector was tilted 90° on its side in order to present the visual images vertically in an appropriate size.

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Results

Results revealed subject TK was slower to identify letters located inside the halo boundary that were congruously colored with his halo (2568.8 ms), compared to any of the control conditions (inside halo incongruous color, 1139.3 ms; outside halo congruous color, 1056.2 ms; outside halo incongruous color, 1055.9 ms). This dissociation was confirmed with a 2×2×10 ANOVA with factors of color congruity (congruous/incongruous), location (inside/outside of the halo border), and target presentation (where along the subject's body the target was presented) applied to TK's response times for correctly locating targets revealed main effects of congruity, $F(1, 138) = 131.0$, $p < .001$, and location, $F(1, 138) = 161.9$, $p < .001$. Furthermore, we found a significant interaction between congruity and location, $F(1, 138) = 123.8$, $p < .001$ (Figure 2). Follow-up *t*-tests revealed TK was most impaired when a blue grapheme (congruous with the blue halo) was presented inside of the border of the halo, compared to either an orange grapheme (providing ample contrast to the blue halo; $t(58) = 9.20$, $p < .001$) or a blue grapheme outside the border of the halo $t(58) = 9.69$, $p < .001$. TK's performance also varied according to target presentation, $F(9, 138) = 4.25$, $p < .001$, such that he was quicker to respond to targets closer to the face on the upper half of the body (1720.9 ms) than to those presented near the lower half (1516.5 ms).

Non-synesthetic control subjects ($n = 4$) tested on a matched procedure showed similar response times across the conditions (inside halo congruous color, 728.0 ms; inside halo incongruous color, 770.8 ms; outside halo congruous color, 745.7 ms; outside halo incongruous color, 807.0 ms), yet revealed main effects of congruity at the group level, $F(1, 3) = 10.6$, $p < .05$, and location, $F(1, 3) = 180.0$, $p < .01$, due to baseline differences in the ability to detect graphemes in each of the conditions. Critically, however, controls showed no interaction between congruity and location at either the individual level (all F values below 0.51, all p values above .48) or as a group, $F(1, 3) = 0.31$, $p = .62$, in a clear dissociation from TK; i.e., blue graphemes were occluded by the halo for TK, but not for the controls. Similar to TK, controls also showed a group level main effect for row, $F(9, 3) = 4.131$, $p < .01$, suggesting all subjects responded more quickly to targets at eye level and near initial fixation.

To examine whether TK's performance significantly differed from that of controls, Crawford and Garthwaite's Revised Standardized Difference Test (RSDT; 2005) was applied to TK and the controls' reaction time data. Comparing congruously colored targets either inside or outside of the aura between TK and controls confirmed the presence of a larger difference in TK than the controls, $t(3) = 11.19$, $p < .01$. Comparing congruously versus incongruous colored targets inside of the aura between TK and controls again confirmed the larger difference in TK, $t(3) = 10.59$, $p < .01$.

The effect of TK's halos on his task performance is equally apparent when considering his accuracy. When a congruously colored grapheme was presented inside of the border of the halo, TK performed at chance (52.5%) for discriminating whether a specific target was an 'A' or an 'M'. However, TK showed perfect accuracy for all other conditions, as were the control subjects for every condition of the experiment. Thus only when the grapheme was occluded by the halo did TK have difficulty discriminating what it was.

EXPERIMENT 2: EMOTION–COLOR SYNESTHESIA

As part of TK's phenomenological descriptions, he reported that when he experiences emotional states or views them in others he indiscriminately experiences a specific color paired with the appropriate emotion (e.g., pride is blue and aggression red). In order to examine the authenticity of TK's emotion–color pairings, we tested the strength of these associations using modified and classic versions of the Stroop interference task.

Methods

Subjects were instructed to read aloud the visual color of either a color word (2 blocks containing 24 trials each) or an emotional word (2 blocks containing, 24 trials each). The order of the blocks alternated between color word and emotional word. Fifty percent of trials were congruous to the respective stimuli and 50% were incongruous; congruity of emotional word colors were based on TK's color associations. Trial orders were randomized. Colored stimuli were presented on a grey background (Arial, subtending 2 degrees visual angle vertically) until a vocal response was produced; vocal onset was registered using an EPrime SRBox response device.

Results

Results from the emotional word condition are presented in Figure 3. TK's mean response times for each condition differed as a function of congruity for both color words (congruous 742.7 ms; incongruous 1035.4 ms) as well as emotional words (congruous 1147.6 ms; incongruous 1461.4 ms). Confirming differences between these conditions, a 2×2 ANOVA with factors of word type (color/emotional words) and congruity (congruous/incongruous) applied to TK's data revealed significant main effects of word type, $F(1, 86) = 21.5$, $p < .001$, and congruity, $F(1, 86) = 11.1$, $p = .001$, and critically showed no interaction between the two, $F(1, 86) = .002$, $p = .96$. Follow-up analyses using an unpaired *t*-test showed significant effects of congruity for both color words $t(45) = 3.49$, $p = .001$, as well as emotional words $t(41) = 2.03$, $p = .05$, confirming TK's reports that emotional words are linked with the experience of color.

Non-synesthetic control subjects ($n = 15$) tested on a matched procedure also showed main effects of word type, $F(1, 14) = 12.5$, $p < .01$, and congruity, $F(1, 14) = 46.4$, $p < .001$, with a critical interaction of the two, $F(1, 13) = 131.0$, $p < .001$; mean response times for color words (congruous 670.5 ms; incongruous 877.2 ms) and emotional words (congruous 686.3 ms; incongruous 674.9 ms). Follow-up paired *t*-tests confirmed this interaction was driven by congruity of color words $t(14) = 9.40$, $p < .001$ with no significant effect of congruity on emotional words $t(14) = 1.09$, $p = .29$.RSDT was applied to these data comparing TK's performance with that of controls. For congruous versus incongruous color words, no significant difference was observed between TK and controls, $t(14) = 0.64$, $p = .53$, confirming similar levels of typical Stroop interference. For congruous versus incongruous emotional words however, TK showed significantly more Stroop interference compared to controls, $t(14) = 6.73$, $p < .001$.

TK as well as controls were highly accurate in both the color word condition (TK 100% accuracy, control's average accuracy 98.6%) and emotional words condition (TK 97.9% accuracy, controls average accuracy 98.2%). Using RSDT to compare accuracy for congruous versus incongruous targets between the conditions revealed no differences in performance between TK and the controls, $t(14) = 0.856$, $p = .41$.

DISCUSSION

The very idea of halos, colors emanating from an individual's 'energy field', is usually met with utmost incredulity and skepticism by scientists; so much so that the renowned magician and archskeptic James Randi has offered a million dollar prize to anyone who can establish their existence. Here we provide the first evidence of the existence of this effect. We demonstrate not only the authenticity of the phenomenon (that it is not made up by the subject) but that colors evoked are perceptually 'real' in the sense of changing detection thresholds and producing Stroop interference in the same manner as real colors.

We propose that halos originate from cross-activation between area V4 and the fusiform face area, which has been implicated in the processing of an individual's identity (Kanwisher, McDermott, & Chun, 1997) paired with networks involved with facial recognition (Gauthier et al., 2000). Additional modulation of this network likely comes from integration with the amygdala, insula and other limbic centers involved in the processing of emotions and social judgments (Phelps, 2006). This is consistent with the observation that the color of a person's halo is also affected by TK's idiosyncratic emotional stance toward him/her.

EMOTION–COLOR TAXONOMY

During our testing we also made another informal observation; we noticed that TK's color for pride was a shade of blue and the color for aggression was pinkish–red. Intriguingly, the color for arrogance is purple, presumably because the combination of blue and red in color–space is purple, and the combination of pride and aggression in emotion–space is arrogance (TK himself had not noticed this coincidence until we pointed it out to him). This observation, if further verified would indicate that TK's color associations are not random. Instead they are the results of a taxonomy of emotions in TK's brain developed through systematically mapping emotional-space represented in the frontal cortices and insula on to color–space in V4 and its projection zones. In a demonstration of this preliminary data, we have mapped several of TK's emotion–color associations in color space (Figure 4), though additional experiments are needed to test this intriguing notion of color taxonomy.

Although presumably evoked through similar mechanisms as in other forms of the condition, TK's synesthesia seems to also be a vital aspect of his conscious understanding of emotions. Evidence of this comes from two observations. First, TK claims that recognition of emotion can only occur after he experiences the color. Second, when TK wishes to express his emotion (e.g., through a facial expression), he must tell himself to 'do green' (in the case of happiness). This not only provides evidence for the necessity of using color to judge emotions, but also provides preliminary evidence that his synesthesia is embodied. Unlike previously reported evidence for embodiment in neurotypyicals which is centered around connecting emotions with facial expressions (Oberman, Winkielman, & Ramachandran, 2007), TK's embodiment appears grounded in his ability to 'simulate' the color of other's emotions with that of his own.

It is well known that strong anatomical links exist in primates between emotions and color (e.g., to detect fruits and rumps in estrus), mediated, perhaps, by connections between v4 and insula which projects to limbic/emotional structures such as amygdala (and also indirectly to frontal structures that may modulate more subtle emotions like arrogance and pride). An enhancement of these connections due to defective pruning or disinhibition would explain why he had more vivid color–emotion links (which were also subsequently enhanced through early childhood training).

Our observations on TK also raise the possibility of a novel therapeutic intervention for patients with autism. Would it be possible to train the child (initially using cues from social context, situation, overt behavior and peoples expressions) to attach color labels to feelings, thereby allowing the child to develop a new internal taxonomy of emotions by mapping them on to his/her color space?

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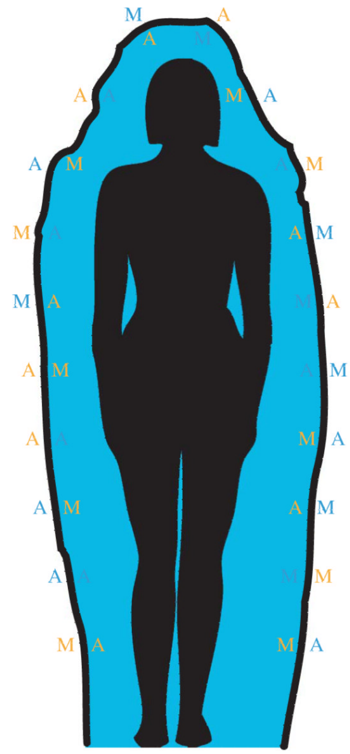

Figure 1.
Experimental setup showing a rendering of TK's reported experiences. Letters are displayed in all locations/colors used in the study. Each side of the figure contains 10 graphemes inside and 10 graphemes outside of the border.

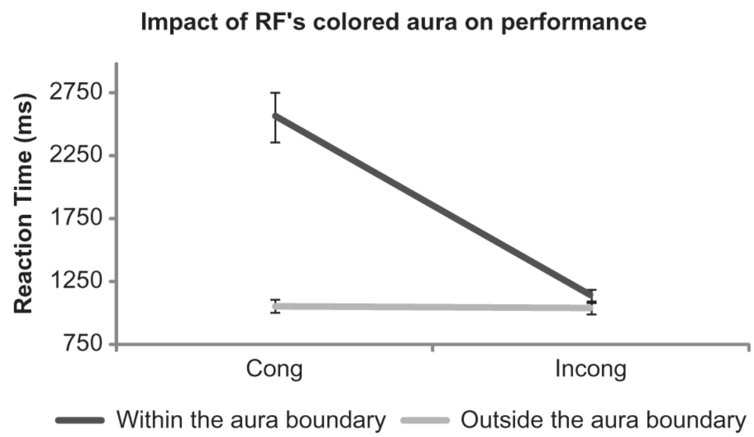

Figure 2.
TK’s reaction times for each experimental condition. Error bars reflect standard error of the mean.

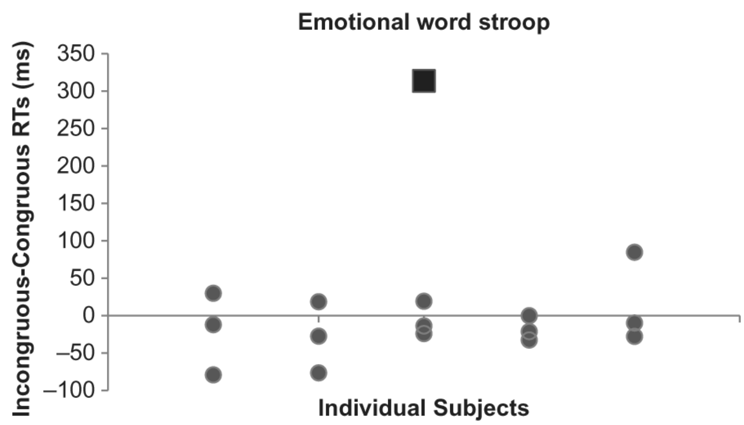

Figure 3.
Effect of color congruity for emotional words in controls (grey circles) and TK (black square).

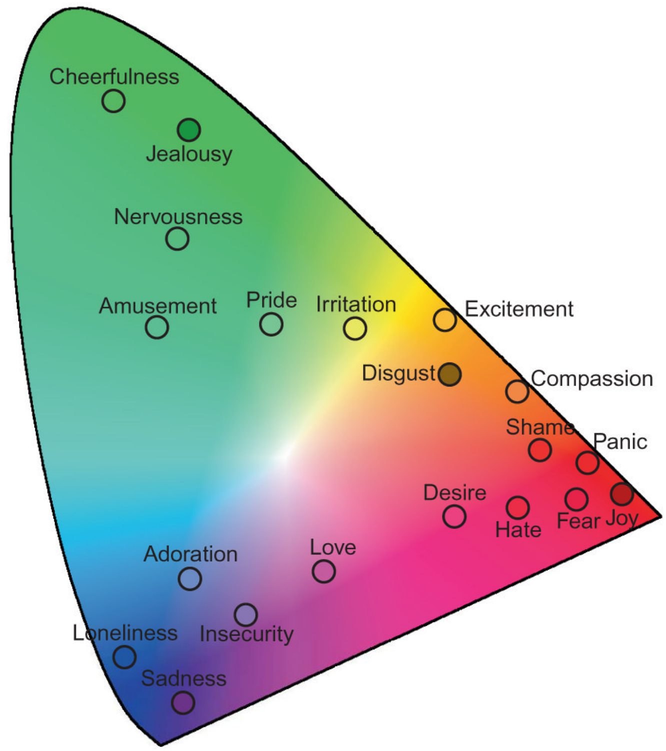

Figure 4.
TK’s emotion–color associations overlaid on a CIE color–space schematic.