

Johan Wagemans, Stefanie De Winter & Christopher Linden

Colour, Pattern, Space and Time in Art Perception: Two Case Studies

1. General Introduction

Remember that a picture, before being a battle horse, a female nude or some sort of anecdote, is essentially a flat surface covered with colors assembled in a certain order. (Denis, 1890, Art et Critique)

When the French artist Maurice Denis (1870–1943) defined a painting as ‘essentially a flat surface covered with colours assembled in a certain order’, he established the intrinsic connection between colour and pattern. In the same famous quote, Denis also alluded to the spontaneous perception of such ordered assemblies of painted colours as objects, scenes and events that could exist in the real world (a female nude, a horse in a battle scene, an anecdote). At the same time, however, he also emphasised the dual nature of a painting (or a picture more generally) as an object of its own (brush strokes on canvas, pencil stripes on paper, pixels on computer screens) as well as things depicted in scenes or ongoing events (e.g. Pagel, 2017; Pepperell, 2015). At the end of the 19th century, partly because of the rise of photography and film, painters became more interested in exploring the nature of painting itself (‘painting is about painting’) and the perceptual effects of colour and pattern as the key components of painting. This theme was quite central in the emerging styles of Impressionism (Claude Monet, Pierre-Auguste Renoir, Camille Pissarro, Paul Cézanne, ...), Pointillism (Paul Signac, Georges Seurat, ...) and Fauvism (André Derain, Henri Matisse, ...); of smaller groups such as *Die Brücke* (Ernst Ludwig Kirchner, Emil Nolde, ...) and *Der Blaue Reiter* (Wassily Kandinsky, Franz Marc, Paul Klee, August Macke, ...); and of post-impressionist painters such as Maurice Denis, Edouard Vuillard, Paul Sérusier, Pierre Bonnard, Vincent van Gogh and Paul Gauguin. Soon after, new styles of art started to explore ways of breaking the spontaneous associations between the ordered pigments and what they could depict (e.g. Divisionism, Expressionism, Cubism and other forms of avant-garde art), and of extending the boundaries of the genres into fully abstract art (both geometric and lyrical abstraction).

In sum, painters use colour and pattern to evoke experiences in those who view the paintings, often meaningful experiences of depicted objects, scenes and events, but in late (or American) Modernism also more abstract experiences of

2D shape, 3D space and time. In this paper, we will present two case studies of art perception to illustrate these more recent trends, one about the Modernist work of Frank Stella, an important American artist who explicitly pushed the boundaries towards paintings as objects and one about the work of Pieter Vermeersch, a Belgian contemporary artist who explores the boundaries between traditional art forms (such as painting, photography, sculpture and architecture) and explicit interventions in space (and time).

2. Part I. Frank Stella

2.1. Frank Stella's modernism

Frank Stella (1936) is probably best known for his *Black Paintings* series (1958–1960) and for his prominent role in representing the Modernist orthodoxy of art works as objects, not intended to be seen as something else but pure form, non-illusionistic, instantaneous and non-spatial. So why would his work feature in a special issue on Colour and Space in Art and Perception? In addition to his *Black Paintings*, Stella also made several series of paintings in which he investigated the relation between colour and pattern, as well as between colour and shape, which eventually culminated in his shaped canvasses. And while the Modernist orthodoxy had norms imposed by art critics for how paintings should be seen, our empirical research has clearly demonstrated that even Stella's art works that were intended to obey these norms are perceived as essentially spatial and non-instantaneous by art viewers who are allowed to look at these paintings.

Figure 1 illustrates this paradox quite nicely. It is an image of the *Artforum* cover of April 2020, which reproduces John Baldessari's (1931–2020) work 'This is not to be looked at' (1974), which in turn displays the *Artforum* cover of November 1966, with one of Frank Stella's *Irregular Polygons* works (*Union III*, 1966) as cover image. With this image, Baldessari alluded to the idea that a viewer's experience can somehow be prescribed. At the time this was published, the search for purity in painting, which was initiated by abstract expressionists, had led to a new orthodoxy that issued norms for how paintings should be seen. These norms were mainly spelled out by art critics such as Clement Greenberg (1909–1994) and Michael Fried (b.1939), and implemented by American Modernist painters such as Frank Stella. In fact, the dialectic between critics and artists that had become dominant in those days (primarily enabled by *Artforum* itself) prevented them (and the art public at the time) from seeing the art works in their full visual complexity. Contemporary art historians (e.g. Elkins, 2003), in contrast, now believe these traditional critics should no longer be looked at, because they did not properly look at the art works themselves. This clash between the theoretical intentions and the actual perceptual effects formed the starting point of the PhD thesis by one of the present authors (De Winter, 2020).

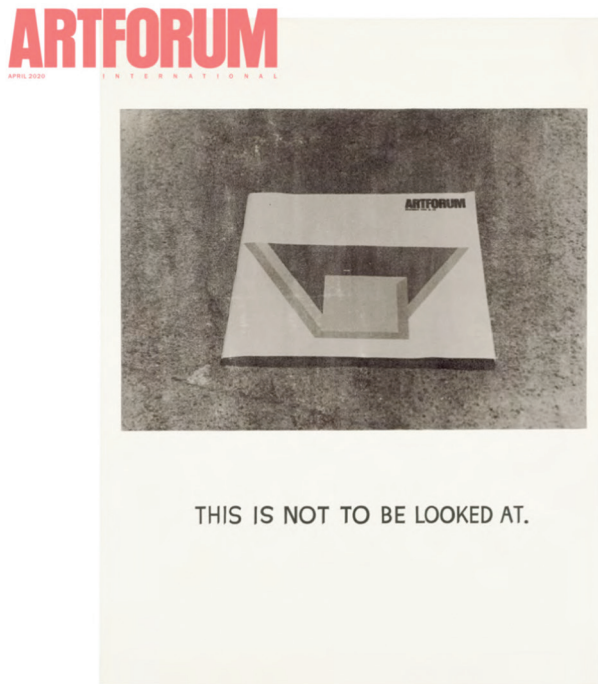


Fig. 1. Image of the *Artforum* cover of April 2020, which reproduces John Baldessari's work '*This is not to be looked at*' (1974), which in turn displays the *Artforum* cover of November 1966, with one of Frank Stella's *Irregular Polygons* works (*Union III*, 1966) as cover image.

Having a background in conservation studies, Stefanie De Winter had conserved some of Stella's works over a decade ago. For some of these works he had intentionally used fluorescent paints to instantiate the Modernist principles of all-overness, flatness, instantaneousness and self-referentiality (see below). In studying the original pigments as well as the artist's archives and the writings about these art works in catalogues, art books and magazines, she noticed that the perceptual effects of the fluorescent paints were often simply ignored or brushed aside as being of secondary importance to the total experience of the art works. One factor contributing to this dismissal has surely been the fact that fluorescent colours cannot be reproduced in photos or on computer screens, so that most viewers looking at reproductions instead of the real art works could not have experienced the effects of fluorescence. In an interdisciplinary project between art history and perceptual psychology, we embarked on a series of studies addressing these issues. All of these studies have been published in journal articles before. Here, we will focus on the main ideas and main findings in the context of the theme of the special issue. We mention only some general aspects of methods and results, and refer to the published papers for more details.

2.2. Spatial Aspects of Frank Stella's Works with Colours and Patterns

The first study consisted of a controlled experiment with stimuli derived from Frank Stella's *Irregular Polygons* series (1965–1966) for which he created 11 shaped canvases that were each being executed four times in four different colour combinations, some fluorescent and some conventional (De Winter, Moors, Van Gelder, & Wagemans, 2018). With these works, Stella claimed to have found a new kind of illusionism, which is completely abstract and not relatable to any classic form of illusion known from traditional art. The point of departure of our study was Stefanie De Winter's observation of illusionistic depth effects caused by the use of fluorescent colours in Stella's art works while she was conserving them and the lack of a nuanced discussion of these strong visual effects in the art-historical literature on these art works. Stella himself was very well aware of these effects, as he said that 'the effect generated by the coloured shapes flip-flopped between flatness and illusion' (Kennedy, 2010, p. 11) causing a 'new way of presenting depth in painting which is more than 2D but less than 3D' (Fried, 1965, p. 5). In the art-historical literature, however, with the exception of Judd (1965), who said that all paintings are illusionistic, critics such as Fried (1966/1998), Rose (1967) and Krauss (1968) either insisted that these works were illusion-less (even flat and frontal) or represented a new type of illusionism (i.e. abstract illusionism), with an emphasis on the material rather than the visual aspects. Note that the role of illusions in research and theories on visual perception is a controversial topic (Braddick, 2018; Koenderink, 2014, 2017; Shapiro, 2018; Todorović, 2018, 2020; van Buren & Scholl, 2018), which we do not discuss further here. For instance, Gestalt theorists did not differentiate between 'illusory' and 'non-illusory' forms of perception.

To focus on the pure colour effects, we isolated the colour combinations of four paintings from this series (see Figure 2, left): *Effingham I*, *Union I*, *Sanbornville III* and *Chocorua IV* (1965–1966). All of these consist of one or two fluorescent colours together with two or three conventional colours. The design of our stimuli consisted of strips of different colours, put next to each other, cancelling out the depth effects caused by form and shape (also the shaped canvas) but respecting their relative proportions and positions. The total set of 15 stimuli also consisted of variations in which the fluorescent colours were replaced by their conventional counterparts and some positions were switched. The participants consisted of 20 artists, 20 art historians and 20 laymen. The experiment took place in a space with ample natural daylight (large window on the side, between 11 AM and 4 PM; see Figure 2, right). All participants rated all coloured strips on a 7-point scale between extremely, strongly and a little protruding (positive scores +3, +2, +1) or receding (negative scores -3, -2, -1), with a neutral midpoint (surface-level with no depth effect).



Fig. 2. Stimuli (left half) and experimental set-up (right half) used in the study by De Winter et al. (2018). In the leftmost column, the top image is *Effingham I*, with four experimental stimuli derived from it underneath: the basic pattern with the original colours, with conventional colours only, with fluorescent yellow replaced by conventional yellow, and with position changes. In the second column, the top image is *Chocorua IV*, with four experimental stimuli derived from it underneath: the basic pattern with the original colours, with conventional colours only, with conventional yellow replaced by fluorescent yellow, and with position changes.

The results were quite clear and can be summarised as follows. First, as expected based on our own observations, fluorescent colours were seen as significantly more protruding ($M = 1.6$, $SD = 1.43$) than the conventional ones ($M = 0.14$, $SD = 1.28$). Second, the depth effect of fluorescent colours was somewhat less pronounced in laymen ($M = 1.42$, $SD = 1.37$) than in art historians ($M = 1.74$, $SD = 1.37$) and in artists ($M = 1.71$, $SD = 1.52$), while the artists tended to assign slightly more depth to the conventional colours ($M = 0.20$, $SD = 1.48$) than art historians ($M = 0.10$, $SD = 1.22$) and laymen ($M = 0.10$, $SD = 1.13$). Third, there were significantly different depth effects between the different fluorescent colours, with fluo pink being perceived as most protruding ($M = 2.30$, $SD = 1.37$) and fluo blue being perceived as least protruding ($M = 0.92$, $SD = 1.32$), and similar depth effects between the different conventional colours, with pink being perceived as most protruding ($M = 0.93$, $SD = 1.26$) and pistachio as most receding ($M = -0.60$, $SD = 1.13$). Note that the strongest fluorescent colour (fluo pink) was perceived as two-and-a-half times more protruding than its conventional variant (pink) but also that the highest-rated conventional colour (pink) was experienced as equally protruding as the lowest rated fluorescent

colour (fluo blue). Fourth, in addition to the pure depth effects of the coloured strips as such, there were also some pattern context effects (i.e. different effects of colour on depth for different basic design patterns) as well as clear colour contrast effects (i.e. different effects of colour on depth for different spatial arrangements of the strips, changing which colours a particular colour is adjacent to). This was especially the case for artists, compared to both art historians and laymen. All in all, this pattern of results demonstrated strong interactions between colour and pattern in terms of their spatial effects (i.e. perceived depth), which are modulated by stimulus factors such as the specific spatial arrangement and by person factors such as art expertise. Such interactions, resulting from stimulus and person factors, were often emphasised and studied in detail by Gestalt psychologists. All of these nuanced perceptual effects can be measured empirically and help to refine the overly generalised and somewhat dogmatic descriptions by art critics and theorists.

2.3. Temporal Aspects of Frank Stella's Works with Colours and Patterns

The second study consisted of a controlled experiment with stimuli derived from Frank Stella's *Moroccan* series (1964) (De Winter, Vissers, Bossens, & Wagemans, 2020). In this series, he aimed to achieve anti-illusionistic paintings (i.e. paintings that do not suggest anything else beyond the painting as an object), which could be perceived instantaneously because of their simple patterns of simple colour combinations and because of the self-referential nature of the industrial paints that he used (i.e. paints that have no reference to paints used in traditional paintings, such as fluorescent and metallic bucket paints). Stella came up with the idea of making instantaneously capturable paintings to follow (and even improve) Greenberg, who had argued that the hallmark of a successful painting is that it should reveal its essence at once: 'Ideally, the whole of a picture should be taken in at a glance; its unity should be immediately evident, and the supreme quality of a picture (...) should reside in its unity. And this is something to be grasped only in an indivisible instant of time' (Greenberg, 1959/1993, p. 80). In essence, this idea refers to the primacy and immediacy of the Gestalt (see Wagemans, 2015, for a historical introduction to Gestalt theory and Wagemans et al., 2012a, 2012b, for extensive reviews of the main findings and theoretical concepts). Stella thought that when a painting could be seen instantaneously, the observer immediately saw the essence of the work and thus the medium (painting), without getting carried away in an illusion of space: 'All I want anyone to get out of my paintings, and all I ever get out of them, is the fact that you can see the whole idea without any confusion (...). What you see is what you see.' (Battcock, 1968, p. 158).

We wanted to test whether these designs could indeed be perceived in an instant and whether the fluorescent colour combinations were perceived faster than their

conventional variants. The starting point were four paintings that had patterns with a central focus point (*Fez I*, *Fez II*, *Marrakech* and *Meknes*) and four paintings with clearly distinguishable colour combinations (*Rabat*, *Marrakech*, *Fez II* and *Tetuan II*). We combined all four patterns with all four colour pairs, to create 16 basic stimuli (see Figure 3, left). To explore the effect of fluorescent colours, each target stimulus was produced as a conventional and fluorescent variant, resulting in a total of 32 target stimuli. The fluorescent variants were screen-printed, using commercial fluorescent inks (fluo yellow, fluo red, fluo orange, fluo green, fluo blue). The conventional variants were printed with an inkjet printer on the same paper, with colours that matched the reproductions of these paintings (RGB (red, green and blue) without fluorescent effect measured from reproductions of the paintings). To be able to display the actual designs as real objects (i.e. not as images on a computer screen), we mounted them on an easel and participants could look at them through a hole. The viewing time was limited to 8 ms, 9 ms and 12 ms by a custom-build apparatus with a shutter that was driven by a micro-controller. The experimental set-up (see Figure 3, right) was placed in a corner office on the fourth floor, allowing sufficient natural light to be present in the room (testing took place on sunny days during spring-time, between 11 AM and 5 PM). The task of the participants was to look at the briefly shown stimuli through the hole, and then report which stimulus they had seen by selecting one of eight patterns shown on a computer screen on their left-hand side. The eight patterns always consisted of the target stimulus shown and seven distractors (selected quasi-randomly from three designs with the exact same colours but a different pattern, three designs with a different colour combination but the exact same pattern, and nine designs with a different colour combination and a different pattern).

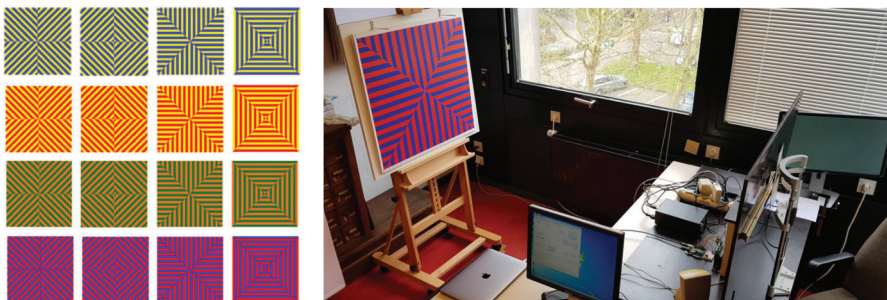


Fig. 3. Stimuli (left half) and experimental set-up (right half) used in the study by De Winter et al. (2020). The 16 basic stimuli were created by combining the four patterns with a central focus point (*Fez I*, *Fez II*, *Marrakech* and *Meknes*, in the four columns, from left to right, resp.) with four clearly distinguishable colour combinations (*Rabat*, *Marrakech*, *Fez II* and *Tetuan II*, in the four rows, from top to bottom, resp.).

The results were quite clear and can be summarised as follows. First, although the stimuli were shown only very briefly, participants were very well able to identify the correct design (i.e. colour × pattern combination) amongst the distractor designs with similar or different colour × pattern combinations (average performance was 86.43% with SD = 9.06%). Second, contrary to our expectation, there was no overall effect of exposure duration and no overall difference between the fluorescent and the conventional displays. Third, there was an overall effect of pattern type, with the fourth pattern (diagonal cross with horizontal lines on top and bottom, and vertical lines on the sides) yielding higher performance levels than the other three patterns. Fourth, there was a significant interaction effect between fluorescence and colour, resulting from specific differences in the red-yellow and green-orange designs (second and third row in Figure 3, left): Red-yellow designs generated the expected effect, with the fluorescent colours yielding higher performance than conventional colours, while the opposite effect was found in the green-orange colours. Further exploration of the type of mistakes made in these cases revealed that for the red-yellow designs, there seemed to be more pattern mistakes in the conventional as compared to the fluorescent type. In contrast, for the green-orange designs, more mistakes of both colour and pattern were made in the fluorescent as compared to the conventional type. Contrast differences in luminance between the two colours of each colour combination might explain part of the results. In addition, the effect of fluorescent colours might have been watered down by the confusion between the hand-printed fluorescent colours and the computer display used for the identification task, which only showed conventional colours. All in all, this pattern of results demonstrated strong interactions between colour and pattern in terms of their perceptual effects induced at very short exposures. On the one hand, these findings provide empirical support for the almost instantaneous perceptual impact of this type of paintings. On the other hand, the lack of an overall effect of fluorescence raises doubts about the self-referential nature of the paints that are used, while the specific colour × pattern interactions that we found suggest that the perception of these simple colour × pattern combinations is somewhat more complicated than the artist and the art critics assumed. Such combinatorial effects are very much in line with Gestalt effects explained by Gestalt theory.

2.4. Spatial and Temporal Aspects of Frank Stella's Works with Colours and Patterns

The third study consisted of a quasi-experimental field study with two real art works and a replica of a real art work by Frank Stella, as well as two equally sized printed copies, hung together with their counterparts, in a dedicated small-scale exhibition in a space at the Van Abbe museum (De Winter & Wagemans, 2022). The focus of this study was on questions related to the perception of these works

by museum visitors, which we assessed by a combination of methods such as mobile eye-tracking, rating scales, questionnaires and semi-structured interviews. In addition to one of Stella's *Black Paintings*, *Tuxedo Park Junction* (which is part of the Van Abbe collection but we no longer discuss here), we included the original *Effingham I* (3 m × 3 m) from the *Irregular Polygons* series (which is also part of the Van Abbe collection) and a handmade replica of *Hiraqla Variation II* (2.5 m × 5 m) from the *Protractor* series (which is in a private collection). Both of these works were created during the height of Stella's anti-illusionistic approach (1967 and 1968, resp.), exemplifying the Modernist logic, and using both fluorescent and conventional colours. Our study was mainly aimed at empirically testing whether the Modernist principles determine the way in which these works are perceived and appreciated by contemporary viewers, whether the colours and patterns have the same effects when actually painted vs. printed, and how viewers explore the two versions of each painting, both spatially and temporally (e.g. which one they look at first, how long they spend looking at each, and how their gazes are distributed over the works across different time periods).

In total, we tested 103 participants who volunteered to visit the 'Tracking Frank Stella' exhibition (2019): 36 laypersons, 24 art historians and 43 artists. For this study, an exhibition space was subdivided into three smaller spaces (with no daylight but lit by spotlights), separated by a corridor that had three openings with curtains, through which participants could enter each room, directly facing the wall that had both versions of the painting. Each room provided enough space for the participants to walk around and comfortably choose a suitable viewing distance (see Figure 4, centre). As soon as they had entered a room, most participants initially looked quickly back-and-forth between the two versions and then walked up to one of them (usually the hand-painted version), visually exploring the overall painting and sometimes scrutinising some specific details.

Here, we can summarise only some of the main findings of this very rich dataset. Comparing the two art works, there was a strong preference for *Hiraqla Variation II* over *Effingham I*, which was also confirmed by the longer visits of these respective rooms (140–170 s vs. 100–125 s). In addition, most participants preferred the original painting over the printed copy, for both *Effingham I* (78.5%) and *Hiraqla Variation II* (75%). This preference for the original was most pronounced in the group of artists, followed by the group of art historians and the group of laypersons. When asked about their preference, 53% of all participants noticed the difference between the painted original and the printed copy for *Effingham I*, while this was the case for only 28.5% of the participants for *Hiraqla Variation II*. Again, the differences between the two versions were more spontaneously mentioned by artists and art historians than by laypersons. These findings were also reflected in the gaze behaviours. In both *Effingham I* and *Hiraqla Variation*

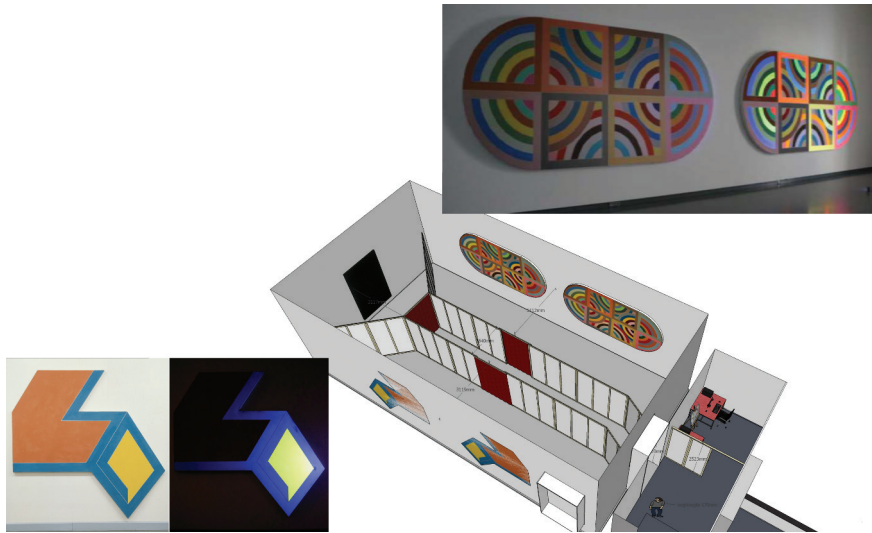


Fig. 4. Set-up and stimuli of the ‘Tracking Frank Stella’ study by De Winter and Wagemans (2022). In the middle is an overview of the exhibition space with the two long rooms displaying two versions each of *Effingham I* (shown below) and of *Hiraqla Variation II* (shown above). For each of these, the fluorescent areas become clear when shown under UV (ultraviolet) light conditions (each time shown at the right).

II, fewer fixations were measured in the copies than in the originals, especially in the expert groups, where some barely fixated the printed copies (describing them as worthless or ugly in some cases).

The heatmaps (i.e. aggregated fixations plotted on top of the image of the painting, in which warm colours represent more fixations) of the original painting and the printed copy of *Effingham I* are generally fairly similar, with more fixations on the yellow part than on the orange part and in the lower left corner and the convexity in the upper half (see Figure 5, top two images). The fact that certain corners received the most fixations indicate that the structure of the painting (emphasised by the shaped canvas) draws the eye more than the planar surfaces painted in a single colour. Note that there are a few small fixation clusters in the middle of the yellow surface due to certain impastos. In addition, there are a few subtle differences between the copy and the original (see Figure 5, top left vs. right, resp.): In the original, some of the corners of the yellow diamond shape received more fixations, while in the copy, the convexity received more fixations, probably because the canvas was wrinkled in that spot (which was not the case in the original). Also for *Hiraqla Variation II*, the heatmaps are generally similar for the copy and the original (see Figure 5, bottom two images) with more fixations on the individually coloured bands in the central area of the painting. Overall, the printed copy received fewer fixations than the painted replica (see Figure 5,

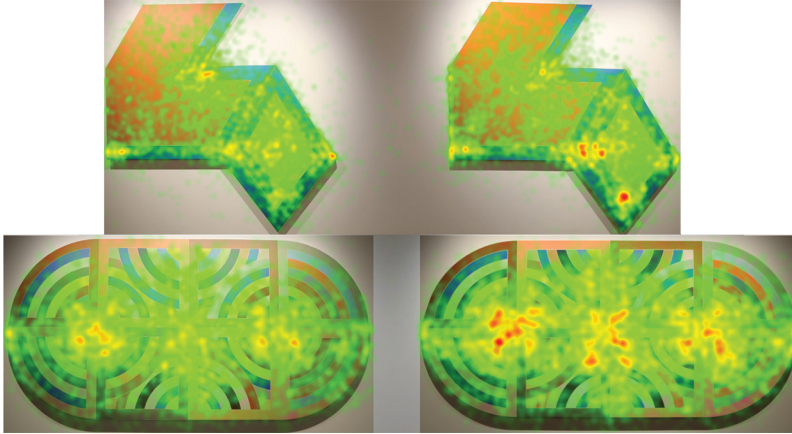


Fig. 5. Heatmaps for *Effingham I* (top) and *Hiraqla Variation II* (bottom), each time the printed copy is shown on the left and the hand-painted version (original or replica) on the right. Warm colours (red, orange) refer to areas with many fixations, cool colours (blue, green) to areas with few fixations.

bottom left vs. right, resp.), especially in the zones around the three central focal points of the configurations, at the intersections where four frame segments meet. Zooming in on the areas of the paintings with fluorescent colours in *Effingham I*, we are able to ascertain that the fluo yellow and fluo blue areas have received more fixations than the conventional orange area. However, the fact that similar differences were found in the printed copy demonstrates that they were caused by the colours and shapes themselves instead of the fluorescence as such. In *Hiraqla Variation II*, the areas with fluorescent colours received more fixations than the other areas both within the painted replica and in the comparison between the painted replica and the printed copy. These findings are in line with the spontaneous mentioning of strong colours in the painted replica of *Hiraqla Variation II* by all participants who had noticed a difference from the printed copy. In *Effingham I*, in contrast, differences in colours were less spontaneously mentioned than differences in materiality.

In the interviews, we also asked participants whether they experienced the paintings instantly or not and whether they experienced depth or not. Regarding the first question, it is striking that the overwhelming majority of the participants reported ‘not instantly’ for *Hiraqla Variation II* (which has the most complex pattern and the most vibrant colours), while the responses were divided more evenly for *Effingham I* (which has a simpler pattern and—especially due to the ageing of the fluorescence—less intense colours). For *Hiraqla Variation II*, only 11.5% of the participants did not experience depth, while 83.5% of the participants did (59% even reported strong depth effects). Note that the fluo yellow and fluo blue areas in *Effingham I* did not generate any depth effects in this study (in contrast

to De Winter et al., 2018), again probably due to the ageing effect of the fluorescence in the real painting here (compared to the freshly screen-printed designs in the previous study).

Feeding back these results to the art-historical claims, a nuanced story emerges. First, we can take the more or less uniform spatial distributions across the paintings as suggestive evidence for their ‘all-overness’, although the strong shifts in spatiotemporal distributions when examining the fixations and saccades could indicate otherwise. Second, regarding ‘flatness’, the majority of participants experienced depth in *Hiraqla Variation II* (with protrusion effects generated by the fluorescence colours, as in De Winter et al., 2020), while in *Effingham I* much less depth was experienced. Third, regarding ‘self-referentiality’, we observed a striking contrast between *Effingham I* and *Hiraqla Variation II* in the mentioning of fluorescent paint and other material qualities. In the descriptions of the experiences of the painting and the copy of *Effingham I*, almost no one mentioned the fluorescent effect, while many participants spontaneously mentioned differences in material qualities. In *Hiraqla Variation II*, the opposite was found: The strong colour effects of the original were frequently mentioned, while other material differences were rarely mentioned. This pattern of results seems to undermine Stella’s logic of flatness through actual materialities of the (fluorescent) paints. Finally, the idea of ‘instantaneously’ appears to be in conflict with the long viewing times and the efforts by participants to explore the paintings (i.e. rather complex wholes consisting of different shapes, patterns and colours) from different distances and angles, especially in the case of *Hiraqla Variation II*. In sum, as in our previous laboratory experiments, this museum study has provided further evidence that the perception and appreciation of the paintings by Frank Stella is very different from the prescribed Modernist logic proposed by the art theorists, which Stella aimed to realise in his works. In subsequent research, we will analyse the eye-movements in more detail, according to different types of exploratory behaviours, viewing modes, and specific alternations between smaller areas of interest to establish objective indications of the important role of perceptual organisation principles (for a review, see Wagemans, 2018) in these paintings (Quétard, Linden, De Winter, & Wagemans, 2022).

3. Part II. Pieter Vermeersch

3.1. Pieter Vermeersch and the nature of his work

Pieter Vermeersch (b.1973) is a Belgian painter, who combines painting with architecture, photography and printing. He often creates installations, in artist-run spaces as well as public spaces, usually spatial interventions with powerful, physical impact on the viewer, inducing experiences that blur the distinctions between

2D and 3D, material and immaterial, and reality and abstraction, as well as space and time. Indeed, in an interview for a recent overview publication, the artist confirmed that ‘his work does not question anything at all, precisely because his own concerns are simply based on the experience of colour, space, and time’ (Küng, 2019, p. 6). Hence, his work seems ideally suited to be included in this special issue. We have exploited the opportunity of a large overview exhibition in M (the city museum of Leuven) in the Spring and Summer of 2019 to study the way in which his works centred around colour, space and time are perceived and appreciated by museum visitors.

3.2. Pieter Vermeersch’s exhibition at M

The exhibition occupied four large spaces (see Figure 6, from bottom to top, following the natural flow of the exhibition, numbered from I to IV). Three parallel walls in three adjacent rooms were painted with extensive colour gradients (for which the artist is most famous): pink in room I, blue in room II and yellow in room III. Several rooms have additional walls built by the artist for this exhibition, in some cases with two layers of different bricks (most notable in room I), on the one hand dividing the rooms and creating subspaces, and on the other hand also connecting the rooms and establishing connected subspaces (which are usually not experienced as such when just strolling along the walls as most visitors do). The artist also provides visual associations between architectural elements and art works, e.g. the long viewing axis from room I to room IV aligns the three door openings with one of the art works (in series 9) on the far-most wall in room IV, and between the light thrown through the windows

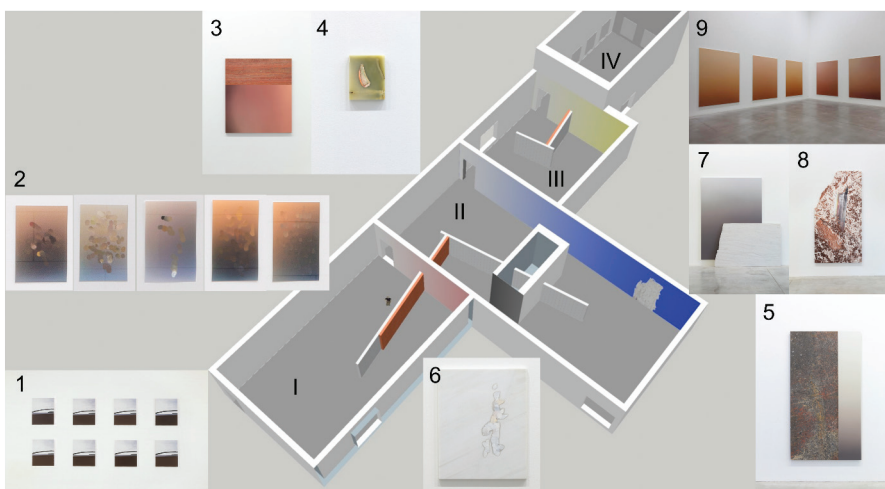


Fig. 6. Layout of the exhibition space of the Pieter Vermeersch exhibition at M, with the four rooms indicated by capital Roman numbers and nine art works indicated by Arabic numbers.

on the floors of rooms I and II with some of the art works. Moreover, he plays with the reflections of some of the glass-framed art works (e.g. on the left wall in room I) and adds mirrors (in the narrow corridor between the left and right parts of room II) for viewers to experiment with the reflections when they move along them. Somewhat related to this, is Vermeersch's use of different layers, for instance, quasi-uniform metallic strips on marbles (works 3 and 5), and splashes or brush strokes of oil paint on metallic plates (series 2) or marbles (works 4 and 8), sometimes with explicit straight edges (works 3 and 5) or shaped contours (work 6). Some of the brush strokes are thin and almost transparent (work 8), while others are thick, leaving a visible shape with distinct spatial features (work 4). In contrast to this, the artist has removed all visible edges between the vertical stripes of paint that were applied when creating the continuous colour gradients for the murals (a laborious work with carefully mixed paints of the same hue and variable amounts of white).

Another very significant spatial component of his work is the use of different scales. The art works vary from as small as 15 cm × 20 cm (for the small marble 4 in room II) to 22 m × 5.5 m (for the blue wall in room II). Vermeersch also introduces series (eight almost identical works in series 1 on the first wall in room I; five almost identical works as group 9 in room IV), partial occlusions (work 7: a pure marble slab standing on the floor, against a painted marble slab hung on the rightmost wall of room II) and embeddings (the five works forming series 2, which were positioned on the left wall of room I, were comprised of quite small oil paintings on C-print, measuring 9 cm × 12 cm, that were framed in much larger frames, measuring 90 cm × 120 cm, and set against a white surround encased behind a glass front). This all affords a lot of global-to-local modes of viewing, taking in the whole work when standing further away or exploring the component works in detail from nearby, a theme that is also very central in Gestalt theory.

Vermeersch's work is also very much about time, in many different ways. Series 1 consists of eight almost identical works hung in a matrix of two rows by four columns, each one a snapshot of a windshield wiper, and each painted separately with tiny little variations between them. As a viewer one can look at them as a whole or as a sequence, trying to notice the differences or to consider them as frames in a (movie) sequence. Series 2 consists of fingerprints of oil superimposed on C-prints. A single fingerprint is a clear trace of an action, and together each individual work is a sequence of actions. At yet a higher level of the spatial hierarchy (from small to large, from local to global), the series allows for a sequential scrutiny of the similarities and differences between the colours of the different backgrounds, as well as the colours and spatial arrangements of the different fingerprints, but only when the viewer

moves along them and watches every one of them in sufficient detail (i.e. taking enough time). Surely, the perceptual processing of these art works has crucial spatiotemporal characteristics worth studying by scientists specialised in human perception, perception and understanding of art, and empirical aesthetics. The marbles incorporate another temporal dimension: from the very long time scale of rock formation (with layers of soils and sediments, sometimes small fossils) to the short-term trace of a quickly applied brush stroke, in some cases ending in a clearly visible drop of oil paint when the brush is lifted off the marble (work 4). The huge blue wall in room II has been partly destroyed by drilling the surface layers away from it, a physically strong, impactful act, perhaps inducing equally strong emotional and bodily reactions in the viewers with sufficient ability for embodied experiences. Again, the study of the effects on museum visitors of these aspects of Vermeersch's work has a lot of questions to try to answer.

3.3. A multi-method museum study on the spatial and temporal aspects of Pieter Vermeersch's work

We have embarked upon such a study, combining mobile eye-tracking, questionnaires and ratings scales. In total, 109 participants volunteered to take part in this study (the majority highly educated and highly interested in art, 34 of whom were real art experts). As a first step, we have developed a taxonomy of navigation and viewing behaviours (Linden & Wagemans, 2021) to be able to code them in the video and eye-movement recordings (their occurrence and duration) and to analyse them as a function of the characteristics of the art works and of the visitors (e.g. level of expertise, familiarity with the artist's work). Here, we can only mention some of the findings resulting from these analyses (for more details, see the original paper by Linden & Wagemans, 2021). First, at a very general level, art gazes ($M_{\text{Frequency}} = 150.2$, $SD_F = 61.1$; $M_{\text{Duration}} = 857.0$ s, $SD_D = 397.6$ s) occurred more frequently and took longer than non-art gazes ($M_F = 40.9$, $SD_F = 32.5$; $M_D = 242.0$ s, $SD_D = 231.1$ s). Second, object scans ($M_F = 52.2$, $SD_F = 27.0$; $M_D = 397.8$ s, $SD_D = 255.4$ s) occurred more frequently and took longer than strolling along ($M_F = 10.8$, $SD_F = 5.5$; $M_D = 132.6$ s, $SD_D = 57.7$ s), turning ($M_F = 27.2$, $SD_F = 13.1$; $M_D = 36.4$, $SD_D = 17.3$) and centring ($M_F = 13.1$, $SD_F = 4.7$; $M_D = 69.8$ s, $SD_D = 31.5$ s). Third, there were no overall group differences in the major viewing behaviours as a function of gender, age, art expertise and interest in art. Fourth, some specific relations were found between different viewing behaviours and different outcome measures. For instance, participants who spent a lower proportion of their time strolling along and a higher proportion of time on alternating gazes more easily saw connections between the pieces in the exhibition.

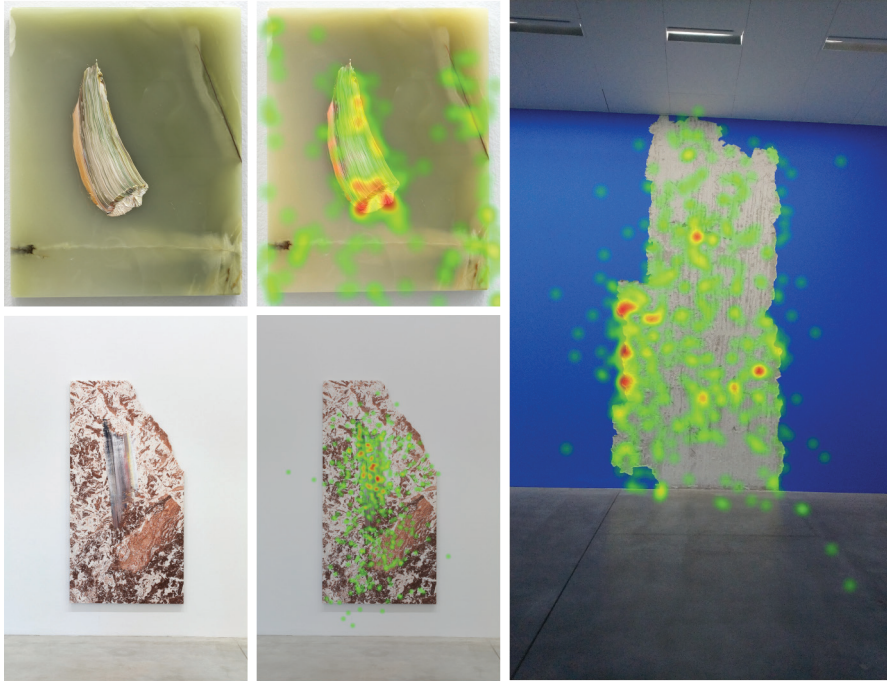


Fig. 7. Some of the art works with their fixations visualised as heatmaps. Warm colours (red, orange) refer to areas with many fixations, cool colours (blue, green) to areas with few fixations.

Finally, we have also analysed the eye-movements for some art works and visualised them in heatmaps (see Figure 7). For two of the marble slabs with superimposed oil paint (works 4 and 8, shown in the left half of Figure 7), it is clear that more fixations were made on clearly visible features in the marble slab itself (e.g. diagonal stripe in the upper-right corner of work 4) as well as on the distinctive visual elements of the applied paint (e.g. even the edges of the brush stroke and the tip of the oil paint left when lifting the brush in work 4). Note that also the shape and surface features are tracked by the fixations on the cut-out piece in the blue wall in room II (shown in the right half of Figure 7). Hence, this ‘trace’ of a cutting act is also taken as a shape with its own spatial features by the visual system, as reflected in the traces of where most viewers’ eyes have landed. From an initial visual inspection of the fixations on the architectural features, it is also clear that visitors also explored the walls (e.g. the coloured murals) and the corners (i.e. where different walls meet or a wall meets a floor or ceiling). Detailed analyses of the spatiotemporal explorations of the full sequence of art works or specific viewing modes (e.g. zooming in or out, scanning left to right, alternating global-and-local viewing, viewing from the side to look at the marble slabs as objects) are still to be conducted. One of the tools we will use are hidden Markov

models to examine the sequence of gazes in particular areas of interest (Quétard et al., 2022).

4. General Discussion

Fine arts, especially painting, but also some installations, some art photography and some graphics (collages, screen prints, etc.), are very much about colour and patterns. Some art styles more than others (e.g. fauvism, *Der Blaue Reiter*, post-impressionism, abstract expressionism) and some artists more than others (e.g. Wassily Kandinsky, Pierre Bonnard, Piet Mondrian, Mark Rothko, Barnett Newman, James Turrell, David Hockney, ...) have produced art works that have a central role for colour, space and their interactions. Colours necessarily imply spatial qualities, as is well known by artists (e.g. Kandinsky, 1912) and vision scientists alike (e.g. Koenderink & van Doorn, 2017, 2022; Koenderink, van Doorn, Albertazzi, & Wagemans, 2015). A full discussion of these issues would require an extensive monograph, with many details on the art history of these styles and artists, and much background and technical information about human vision, along with findings from phenomenology, psychophysics and neurophysiology, and some attempts to integrate their insights into coherent theories. No matter how useful and interesting, such an elaborate treatment is clearly beyond the scope of the present article (and such integrative theories are largely missing anyway).

Instead, we have chosen to focus on two artists, Frank Stella, a well-known Post-War American abstract painter, and Pieter Vermeersch, an emerging Belgian abstract painter, representing a contemporary trend to break the barriers between artistic disciplines. The works of both of these artists are very strongly focussed on the role of colour and pattern in relation to space and time: Stella adhering to the Modernist logic of non-illusionistic, non-spatial, non-referential art as object, perceived instantaneously, Vermeersch exploring ways to enhance the viewers' spatial and temporal experiences through complex art installations with multiple objects and architectural elements interacting with each other and with the spaces in which they are embedded. While Stella wants to avoid as much as possible that the viewer has to process the art work ('what you see is what you see' in a single glance), Vermeersch wants the museum visitor (or the accidental viewer passing by his art works in public spaces) to explore the spatial properties of colours as applied on surfaces (as gradients, brush strokes, or fingerprints), sometimes with edges facilitating almost automatic figure-ground segmentation, sometimes with more complex patterns and forms. Such explorations definitely require time (and some effort and expertise with extended looking) before the full experience of the rich spatiotemporal characteristics emerges and deep

questions about space and time might arise. Art-theoretical claims and our own intuitions of how these art works operate, in terms of their visual perception, (aesthetic) appreciation, and (bodily and cognitive) understanding, are empirically testable. This was demonstrated here by four studies, using a variety of methods, some well-controlled laboratory experiments with carefully manipulated stimulus factors and carefully measured perceptual effects and some quasi-experimental museum studies in which participants with different levels of art backgrounds (laypersons, art historians, artists, art lovers) move around while their eye-movements are tracked, followed by ratings, questionnaires and semi-structured interviews. We believe we have just started to scratch the (multi-coloured) surface of this extensive space of research possibilities afforded by art works that play with colour, pattern, space and time. With this overview paper, we hope to stimulate more artists and scientists to engage in collaborative efforts on this path.

Summary

Colour and space are pervasive topics in both perception and art. This article investigates the role of colour and pattern in relation to space and time in the art works by two artists: Frank Stella, a well-known Post-War American abstract painter, and Pieter Vermeersch, an emerging Belgian abstract painter, representing a contemporary trend to break the barriers between artistic disciplines. While Stella adheres to the Modernist logic of non-illusionistic, non-spatial, non-referential art as object, perceived instantaneously, Vermeersch explores ways to enhance the viewers' spatial and temporal experiences through complex art installations with multiple objects and architectural elements interacting with each other and with the spaces in which they are embedded. We discuss these major themes in some representative art works, and in the way they are perceived and appreciated by contemporary viewers, investigated in four empirical studies: two laboratory experiments using well-controlled stimuli derived from art works, and two museum studies employing a variety of methods, including mobile eye-tracking and questionnaires.

Keywords: painting, art, colour, space, time.

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Author's Biography

Johan Wagemans (b.1963) is a full professor in experimental psychology at KU Leuven. For several decades he has investigated human visual perception using a combination of methods (phenomenology, experimental psychology, psychophysics, computational modelling, neuroimaging and neuropsychology). His current research is focussed on perceptual organisation in relation to visual art and aesthetics, funded by a long-term structural grant from the Flemish Government (Methusalem) and an ERC Advanced Grant.

Address: Department of Brain & Cognition, University of Leuven (KU Leuven), Tiensestraat 112, Box 3711, B-3000 Leuven, Belgium

E-mail: johan.wagemans@kuleuven.be

Orcid: 0000-0002-7970-1541

Stefanie De Winter (b.1986) is a postdoctoral researcher at KU Leuven. She is an art historian with a background in painting conservation. For her PhD, she investigated Frank Stella's fluorescent works using an interdisciplinary approach, combining art history with conservation studies and vision science. Her current project addresses ageing in Colour Field painting and attempts to reconstruct the original state of the works through augmented reality.

Address: Department of Brain & Cognition and Art History, University of Leuven (KU Leuven), Tiensestraat 102 - bus 3711, 3000 Leuven

E-mail: stefanie.dewinter@kuleuven.be

Orcid: 0000-0002-7551-2444

Christopher Linden (b.1992) is a PhD candidate at KU Leuven. His current research examines the role of the museum context in art perception and aesthetic experiences. He utilises mobile and stationary eye-tracking to explore how art viewing strategies differ across museum and laboratory settings.

Address: Department of Brain & Cognition, University of Leuven (KU Leuven), Tiensestraat 102 - bus 3711, 3000 Leuven

E-mail: christopher.linden@kuleuven.be

Orcid: 0000-0003-3086-9375