Instantaneous Art?
Investigating Frank Stella's Moroccan Paintings with a Short-Exposure Experiment

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Abstract

In his search to create 'instantaneously capturable' paintings, Frank Stella started to use Day-Glo alkyd paints as a vehicle to communicate his simple, striped designs. Up till now, art criticism has neglected the visual impact of these fluorescent colours on this concept of 'instantaneous art'. By presenting participants with Stella's designs (fluorescent and conventional variants) for short presentation times (8 to 12 ms), we aimed to find out whether fluorescent colour combinations are seen faster (i.e. yield better performance in identifying the specific design) than their conventional counterparts. In general, participants were very good in identifying the correct design among distractors, which means that the pattern and colour combinations based on Stella's work do seem to be 'instantaneously capturable'. However, Stella's formula for 'instantaneous' paintings is not identical for the different combinations. When exploring fluorescence in combination with other aspects of the design (colour and pattern), we found two effects that seemed to predict performance. First, performance seemed to depend on specific design patterns. Second, fluorescence seemed to interact with specific colour combinations in predicting performance. The red-yellow designs yielded better performance for the fluorescent variants, while the opposite was found for the green-orange designs. Contrast differences in luminance between the two colours of each colour combination might explain part of the results. On the other hand, 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.

Keywords

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Instantaneous perception, gist perception, perception of paintings, fluorescent colours, isoluminance, Frank Stella, Moroccan series

1. Introduction

In an earlier investigation into the impact of fluorescent colours in Frank Stella's (°1936) *Irregular Polygons* (1965-66) paintings, a significant difference was found between the depth perception of fluorescent colours and their conventional variants (De Winter et al., 2018). The study showed that the fluorescent colours, in general, were experienced as strongly protruding. These results were inconsistent with the art criticism about 'anti-illusionism', a quality that was attributed to the Irregular Polygons by Michael Fried (°1939) because of their flat and frontal appearance (Fried, 1966). Importantly, we also showed that the depth experience gets lost when only observing reproductions (without fluorescent colours) of the artworks. All in all, by using perceptual experiments as an inter-subjective validation, our findings made it possible to adjust some of the art-historical claims from the 1960s based on (colour) depth perception in these paintings (e.g. flatness, anti-illusionism). Because various theoretical concepts that are related to certain perceptual experiences have been attributed to Stella's artworks, more interdisciplinary research is needed in order to re-evaluate them. For this paper, we examined the concept of 'instantaneousness' in Stella's Moroccan paintings through a short-exposure experiment. Like the experience of spatiality (cf. illusory colour depth), instantaneousness played an equally important role in the reception of Stella's work.

As stated in the introduction of our first study on the art and perception of Stella's work (De Winter et al., 2018), traditional art theory often lacks persuasiveness due to the degree of subjectivity of certain claims. In the case of abstract art, the evaluation of the quality of artworks is often based on judgements on the character of the perceptual experience of single individuals. These judgements nevertheless constitute truth claims, which need to be investigated regarding their intersubjective validity, if possible. In this case, specific claims about instantaneousness get "temporarily exported away from art history, into psychology, where they become the subject of a controlled experiment, which has the goal to either refute the claim or to give it objective validity" (De Winter et al., 2018, pp. 117-118). Just like the previous study, the outcome of this second study will be "reimported into the art-historical practice, wherein the case of invalidation, it leads to a revision of the original argument" (De Winter et al., 2018, pp. 117-118).

The set of fluorescent paintings studied here belongs to Stella's Moroccan paintings which is part of a larger group of series that he executed with different industrial paints such as black, aluminum, and copper alkyd paints. All of them were products of his attempts to try to achieve anti-illusionistic paintings. According to the artist, the reason why his paintings are instantaneous is twofold: firstly, because of their simple patterns filled with simple colour combinations and secondly, because of the self-referential nature of the paints. In the literature, however, no distinction was made between the different effects of the paints he used (e.g. aluminum, copper and fluorescent paints). All of them fall under the same category of 'instantaneous paintings', without nuancing their individual appearances. Another problem is the loss of the specific (fluorescent) effect when observing reproductions (through books and online sources) of these artworks, which often form the only reference when investigating these artworks.

The present study was a first attempt to distinguish possible differences between the perception of the original (with fluorescent colours) Moroccan paintings and their conventional coloured reproductions. To be precise, we wondered whether the fluorescent colours can increase the speed of grasping of the patterns. We expected that the fluorescent colour combinations, because of their intensity, were more instantaneous than their conventional variants. If our hypothesis is correct, then this study has strong implications for the art-historical practice. In general, the study reveals new insights into the impact of fluorescent colours in Stella's works: whether these designs can be seen effectively in an instant and whether there is a connection between the speed of capturing them and the use of fluorescent paints.

The Moroccan series consists of paintings (see, for example, *Marrakech* in fig. 1) that are similar variants (simple symmetrical patterns and simple colour combinations) of the same size (2m by 2m) (note 4). Their designs are products of a 'formula' predetermined by the artist, which he investigated through various sketches (note 1). The simplicity of the designs allowed us to single out the depicted image (pattern and colour combination) and use them as stimuli, which could be compared in our study. In order to compare the impact of the different versions, a short-exposure experiment was designed in which we focused on the comparison of two-colour types (fluorescent and conventional), four different colour combinations and four different patterns. Because physical stimuli —one set of hand-printed fluorescent versions and one set of inkjet-printed conventional variants— were used, a custom-made setup was developed. The stimulus selection, design and execution, and the experimental setup are discussed in the Method section. Before presenting the actual experiment, a brief art-historical context on the genealogy of the concept of instantaneousness will be given, followed by a determination of the velocity of the instantaneous event in Stella's works. Thereafter, an overview of insights that we found in other studies will be presented, complemented with our research questions and hypotheses. The final part will focus on the results, first by providing a general analysis of the performance, followed by more detailed results from each individual design group, in which we will zoom in on the performance rates of the different colour combinations and colour types in relation to the different patterns.

1.1. Art-Historical Background: Frank Stella's Moroccan series and the concept of instantaneousness

The American art of the 1960s was strongly influenced by the emerging of mass production and the speed of image communication through, for example, the invention of television and the advance of advertising. Back then, the prosperous American Zeitgeist contributed to an artistic turn, which resulted in movements like Pop and Minimal Art. A group of young artists, started to question the modernistic concepts (like flatness) which had formed almost the entire art scene shortly after the Second World War. These concepts were developed by the abstract expressionists and defended by their patron, the famous art critic Clement Greenberg (1909-1994). He had brought up the quality of "at-onceness" (Greenberg, 1993, p. 80) as a mark of a successful painting, which meant that a painting should reveal itself at once (instead of making the observer wander over the painted surface), allowing the observer to have a split-second experience (Greenberg, 1975). In 1959 he explained this idea in his text *The Case for Abstract Art*: "[…] 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, the highest measure of its power to move and control the visual imagination, should reside in its unity. And this is something to be grasped only in an indivisible instant of time" (Greenberg, 1993, p. 80). Greenberg appropriated the quality of at-onceness to paintings like Jackson Pollock's drip art, because, according to him, in his paintings, the medium itself was visualized. In the 1960s these modernist claims were re-evaluated and further refined by the Pop and Minimal artists. According to them, observing these expressionist paintings still caused a traditional form of spatial illusion because of their complex pictorial surfaces, which meant that they could not be seen in a single glance (at once). Frank Stella was one of the first artists among them to respond to the Modernist idiom. He understood that in order to be relevant as an artist, he had to please Greenberg, and that is precisely why he wanted to eliminate illusionism in painting as much as possible, which led him to take the concept of at-onceness very literally. He came up with the idea of making 'instantaneously capturable paintings', to better approach the Modernistic standards as claimed by Greenberg. 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 caught away in an illusion of space. In an interview with Bruce Glaser he said: "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... […]" (Lippard, 1995, p. 158).

When asking art historian Barbara Rose about Stella's fascination with the speed of capturing images, she simply said: "Frank is a speed freak. He played lacrosse, squash, and tennis. He owns a stable of Arabian racehorses and he has many race-car-driver friends. He always went to the races. Speed is throughout his work and part of his character" (De Winter, 2018). During that time, he was a huge fan of the spectacular home run hitter, Ted Williams. Stella was fascinated by the speed with which he saw the ball coming, he said: "Williams sees faster than any living human" (Krauss, 1990, p. 283). According to Rose, "he sought the instantaneous" throughout his art. "For Stella", she said, "speed was American, not the futurist illustration of motion, but condensed time" (De Winter, 2018). Stella's fascination with speed emerged in his art in which he sought the ultimate fastness of capturing images. Back then, he admired artists like Roy Lichtenstein, who were trained in fast drawing of images, because they often exercised drawing sessions in so-called 'flash-labs' (Clearwater, 2018). When communicating his concept, Stella wanted direct, "non-relational" (Rubin, 1970, p. 21) paintings whose totality was immediately visible: "I wanted something that was direct –right to your eye … something that you didn't have to look around– you got the whole thing right away" (Rubin, 1970, p. 30). In order to achieve such a "visual imprint" (Rubin, 1970, p. 30) from a painting, he developed a formula. All of them were designed with simple patterns, which he filled with simple colour combinations for which he used so-called 'specific' materials like industrial metallic and DayGlo fluorescent paints. He chose these specific paints because, according to him, they create a self-referential paint skin, in that they only refer to themselves and nothing else in traditional painting or nature. He found that this quality adds to the immediate grasping of the image of a painting (Rubin, 1970). When the first author asked Rose whether she thought he used fluorescent colours for their capacity to automatically attract the eye, she said: "Yes, although perhaps not consciously" (De Winter, 2018). Nothing was found in the literature about Stella's conscious choice for fluorescent paints that could be related to the speed of capturing his paintings.

After Stella's instantaneous paintings had been displayed, art critic Michael Fried, who was a student of Greenberg, confirmed Stella's intentions by praising "the power of his pictures derived from the clarity and speed with which their patterns 'stamp' themselves out retinally" (Fried, 1966, p. 6). Later, Rosalind Krauss placed Stella's paintings under the category of "visual modernism": "the image performed the condition of an abstracted and heightened visuality, one in which the eye and its object made contact with such amazing rapidity that neither one seemed any longer to be attached to its merely carnal support […]. Vision had, as it were, been pared away into a dazzle of pure instantaneity, into an abstract condition with no before and no after" (Krauss, 1990, p. 284). Opposite to Greenberg and Fried stood a group of artists who defended the temporal experience. Donald Judd (1928-1994) openly plead for a temporary experience in which viewing art should become a process (Judd, 1965). Robert Morris (1931-2018) reconciled both views by claiming that art must have the potential to initially attract the viewer's attention after which she can take the time to grasp the work in its entirety. Here one can speak of a timeless flash, followed by a temporary experience (Morris, 1968). In a more recent text, Van Gelder (2003) stated that one cannot corroborate this theory and that it remains a personal choice whether or not to accept it as a spectator.

The literature on instantaneousness in art contains multiple arguments, which each defend a different temporal experience in the observation of artworks. When focusing on the specificity of the DayGlo materiality, Stella's intentions seem paradoxical, because he wants to obtain a similar visual imprint through all paintings of various series, made with different complex-looking industrial paints. It is questionable to what extent the self-referential aspect can be compatible with the instantaneous quality in DayGlo paintings and whether this differs over works (different colours and patterns). This brings up the theory of "twofoldness" (initially developed by Richard Wollheim (Wollheim, 1987)), which argues (in follow-up to Greenberg's concept of medium specificity) that in order to perceive and appreciate a painting, two different experiences should unfold simultaneously: on the one hand the consciousness of the surface, and on the other that of the depicted image (Winters, 2003). If we extend this reasoning to Stella's case, who claimed that his paintings are instantly visible, partly through the use of self-referential paints, then all observers should be instantly aware of the depicted image (coloured pattern) as well as its surface that is made of fluorescent paints. However, as indicated in the introduction, all claims about instantaneousness and self-referentiality are based on first-person appreciations and phenomenologies by experts. To better understand the impact of fluorescent paints in these artworks and what remains valid from the arguments about their perceptual qualities, studies must be conducted to give the theory an intersubjective validation.

[INSERT FIGURE 1 ABOUT HERE]

1.2. The Speed of Seeing: determining the velocity of the instantaneous event in Stella's works

In the art theory of the 1960s, the term 'instantaneous' was used as a quality label, which changed the original meaning of the word. Before we present the experiment, it is necessary to first indicate the semantic levels attached to the term 'instantaneous' and, secondly, to propose a definition of 'instantaneous' for art theory.

According to Oaklander, instantaneousness means the absence of duration, though it still is a measurement of time which amounts to the occurrence of a very short event (Oaklander, 2014). According to Piéron, the perceptual meaning of instantaneousness could be defined as a "punctiform element of temporal extent" (Piéron, 1923, p. 9-10). In other words, when you consider 'durability' as a horizontal line of continuous events, then the 'instant' is just one single point on that line. Vicario and Zambianchi described several experiments in which they searched for the threshold between instantaneousness and durability. They wrote: "instantaneousness is the perceptual feature of a momentary breaking of a steady status of the temporal field that leaves that status unchanged, only marking the separation of the event "status before" from the event "status after". On the other hand, durableness is the main feature of an event that takes its place in between other events, separating them or giving rise to a double representation" (Vicario & Zambianchi, 1998, p. 50-51). In their discussion, they indicated that they were not convinced of the perceptual meaning itself of the terms with which the temporal properties of such short events are described: "For instance, we call 'instantaneous' events of which cannot be said that they are durable, but we call 'instantaneous' facts that, strictly speaking, are not events, since they are void of contents" (Vicario & Zambianchi, 1998, p. 49-50). In this manner, it is doubtful whether 'instantaneousness' is the ending point of even shorter durations, or as a category disjointed from 'durableness'. These characterizations of instantaneousness seem to be oxymoronic. However, we must not lose sight of the art-historical context in which the term instantaneous was launched. Stella used this indication of time as a measure to indicate the 'fastest capturable' of all paintings. Stella took the search for the essence of painting very literally and reasoned about what a painting should look like in order to still be memorable after a short moment of exposure. In Stella's case, therefore, 'instantaneous' stands for the shortest possible time in which a percept can become conscious. In order to be able to see the painting as a whole in an instant, Stella developed paintings in which he weighed all the steps in the creation process with their possible improvement in terms of rapid visibility and strong memorability. This resulted in the development of simple patterns with simple colour combinations.

In everyday life we generally have the impression that perception is instantaneous: From the moment we open our eyes, we clearly see the world around us and quickly extract information and meaning from it. Perception research has demonstrated over and over again, however, that such an impression can be misleading, because the amount of processing involved can be enormous and not all aspects of perception are given "all at once". Nevertheless, there is a long tradition of trying to establish experimentally what can be seen at short exposure durations. Building on early work in the Leipzig school of Gestalt psychology, in which the stepwise emergence of Gestalten ("Aktualgenese" or "microgenesis") played a central role (for review, see Flavell & Draguns, 1957), experimental psychology has addressed the time-course of visual perception (e.g. Hegdé, 2008) and other cognitive processes (e.g. Bachmann, 2000) in series of experiments with short, often masked exposures. For instance, studies have found that when presented with real-world images, people are able to detect objects based on presentations as short as 50 ms and to recognize objects after only about 100 ms of presentation (e.g. Fei-Fei, Iyer, Koch, & Perona, 2007; Grill-Spector & Kanwisher, 2005). Even this fast processing comprises different stages, however. Fei-Fei et al. (2007) found that before 40 ms, sensory-related features (light–dark) are dominant for people's perception of stimuli, while from around 50 ms of presentation, a shift to more object-related features occurs. An MIT study from 2013 showed that in order to recognize an entire image, the visual apparatus only needs 13 ms (Potter et al., 2014), which is almost ten times faster than the 100 ms suggested by previous studies.

Another line of work, about ultra-rapid categorization, using a go/no-go task (e.g. Thorpe, Fize, & Marlot, 1996; Wu, Crouzet, Thorpe, & Fabre-Thorpe, 2015), showed that the basic object level is not necessarily the semantic information activated fastest during visual processing. When a naturalistic image is presented briefly (20 ms) and participants are asked to indicate whether a predefined basic (e.g. dog) or superordinate (e.g. animal) object class is present in the display, participants were able to do this nearly perfectly (Thorpe et al., 1996). In addition, they were consistently faster at detecting an object at the superordinate than at the basic level (Wu et al., 2015). Similar findings were obtained for scene gist categorization in which participants have to judge the broad semantic category of the presented scene picture (e.g. Kadar & Ben-Shahar, 2012; Rousselet, Joubert, & Fabre-Thorpe, 2005): Participants were faster at distinguishing natural or manmade (superordinate scene level) than sea or mountain (basic scene level). Using similarly complex photographs of scenes as stimuli, Castelhano and Henderson (2008) found that besides structure, colour also plays an important role in the activation of scene gist. According to them, colour has a direct connection to the conceptual representation of scenes and in some cases, depending on the scene, colour provides more valuable information than structure (Castelhano & Henderson, 2008).

In the domain of empirical aesthetics, Cupchik and Berlyne (1979) explored how fast people could discriminate so-called collative properties of paintings, referring to the relationship between elements within the stimulus (e.g. the degree of ambiguity, complexity, and familiarity) and whether these collative properties had an effect on perceived pleasingness. The results of this study showed that participants are able to discriminate collative properties (and paintings varying on those properties) very quickly, with presentation times of 50 ms being enough to extract the relevant visual information. Bachmann and Vipper (1983) replicated and extended these findings to even shorter presentation times (down until 1 ms, which is probably as close as one can get to "instantaneous" but note that the flashed stimuli were not masked). Locher, Krupinski, Mello-Thoms, and Nodine (2007) took a more general approach to the time course of art perception to find out in what order different aspects of artworks are perceived. Based on their subjects' free reports and eye movements, they proposed that the change in pictorial properties of a percept (e.g., symmetry, complexity, structural features) might already reach a highly advanced stage after about 100 ms. Based on the finding of a significant correlation between pleasingness ratings at 100 ms and at unlimited presentation times, it seems that people can extract enough information from 100 ms to form a significant holistic impression of the semantic meaning (i.e., gist) of paintings, including expressive aspects and 'meaningful' aesthetic judgements. Extending this work to more specific properties of artworks, Augustin, Leder, Hutzler, and Carbon (2008) found that processing of content in art can already be traced after 10 ms glances and is already strongly developed after presentations of around 50 ms, whereas style processing emerges from about 50 ms of presentation and develops more slowly. More recently, Verhavert, Wagemans, and Augustin (2017) presented 54 reproductions of paintings of 18 different art styles from the 15th century to the 1960s at different presentations times (10, 50, 100 and 500 ms in Experiment 1 and 20, 30 and 40 ms in Experiment 2) and found that aesthetic evaluations at short exposures were already wellcorrelated with those at unlimited presentation time, especially for 'beauty' and 'specialness' (somewhat less so for 'impressiveness').

In summary, this short review of the speed of perceptual and aesthetic processing demonstrates that a great deal of relevant information can be extracted from very brief glances (even only 10 ms). However, none of these studies specifically investigated on colour and pattern information in compositions like those of Frank Stella, let alone focusing on fluorescent colours.

1.3 The impact of daylight fluorescent colours on the velocity of the instantaneous event

A daylight fluorescent colour differs from a conventional colour in that these pigments absorb energy of the short-wavelength range of the visible light and re-emit this energy over a narrow range of longer-wavelength light. As a result, such a fluorescent surface appears to glow by itself because the pigment converts more light than was originally present in the light of the surrounding area, causing it to appear as a very bright, radiant colour (Livingstone, 2002). We could only find a few studies on the speed of processing and its effect on the visual short memory for fluorescent stimuli. Earlier research into visual salience and accelerated visibility among observers shows that the intensity of colours plays an important role in faster seeing and longer holding of an image. An investigation into the degree of visual attention that sponsor boards received from sports viewers on television, showed that luminance and colour contrast have a significant influence on a person's focus-time (Breuer & Rumpf, 2015). The viewers' preference is also influenced by brighter colours: Milosavljevic et al. (2012) found that items with brighter packaging are more likely to be chosen, because of the visual salience bias. In the 1950s and 1960s, Day-Glo corporation committed itself to promoting fluorescent colours for signalization and advertising. For that, they conducted an eye-tracking study that compared fluorescent versus non-fluorescent boards in direct light versus indirect light with a simulated drive through the New York and New Jersey area. They measured the time it took for subjects to first notice the outdoor boards. They found that the brightness and boldness of their fluorescent colours had better results than their conventional variants. With their campaign, they claimed: "Day-Glo fluorescent colour is seen sooner (according to them, a fluorescent colour is noticed after 1.2 seconds and conventional colours only after 2 seconds)" and "DayGlo fluorescent colour holds reader attention longer" (according to them, a fluorescent colour is observed for 1.3 seconds and a conventional variant only for 0.6 seconds). (DayGlo corp, n.d.)

[INSERT FIGURE 2 ABOUT HERE]

Although this does not provide any information on the fact that they can be seen faster at a very short amount of time, we hypothesized that fluorescent colours, more than their conventional variant, can increase the perception and subsequent memorability of the pattern after short exposure because of their intensity (higher luminosity). In order to find out their threshold, we decided to test the designs at 3 different times (8 ms, 9 ms and 12 ms). Our limit was 8 ms because this was the fastest possible time in which the *Uniblitz VS-25* shutter (*Vincent Associates*) shutter could open and close (see section 2.3).

1.4. Research Questions and Hypotheses

Starting from the main art-historical question on the impact of fluorescent colours on the 'capturing-time' of Frank Stella's Moroccan paintings, we developed an experiment in which two art-historical claims related to the *instantaneous* and *self-referential* nature of the work of Frank Stella were examined. Specifically, the claims were tested with conventional and fluorescent variants to explore the assumed role of fluorescent paint as causing these effects.

<u>1) Are the designs based on Frank Stella's Moroccan paintings experienced 'instantaneously'?</u>
To explore the 'instantaneous' nature of the works, participants will be exposed to the works very shortly (8-12 ms) and will be asked to identify the correct target design among distractor designs. Performance levels will be explored to determine how easy it is for participants to instantly 'grasp' the designs. We will explore the effect of exposure time, colour combination and pattern colour combinations on performance levels to see which designs are most instantaneous.

<u>2) Does fluorescent paint amplify the 'instantaneousness' effect?</u>
Performance on the conventional designs will be compared with performance on the fluorescent variants to see whether fluorescent variants amplify the 'instantaneousness' of the design, leading to better performance. Again, we will explore this for different pattern x colour combinations. Based on the art-historical claims, it is expected that participants will perform

very well on the task. However, as mentioned in the introduction, Stella and the art critics did not specifically link the effect of fluorescent colours to the instantaneous quality of these paintings in the literature. In contrast, Stella himself claimed that the self-referential materials (such as aluminum, household paints, but also fluorescent colours) are contributing to the instantaneous grasping of the works (as mentioned in Section 1.1 about the art-historical background). This will be examined by observing whether participants spontaneously noticed the fluorescent effect of the colours or the difference between conventional and fluorescent variants.

2. Method

2.1 Participants

We invited 40 psychology students (34 female) with normal or corrected to normal vision. Before the start of the experiment, subjects first took the Ishihara colour test (note 2) to ensure that no one had deficits in colour vision. The largest part of the group (34) did not have artistic experience (no practical art or art-historical background). One participant was a first-year student in art history and five other participants had joined art classes (in part-time art education). Most of them (4) followed classes in performance art (like music and drama) (10%) and only one of them in visual arts (including painting and drawing). Four participants claimed to have a little knowledge of Frank Stella but none of them recognized that the stimuli were based on his work.

2.2 Stimuli

The starting point for the target stimuli were the works from Frank Stella's Moroccan series: *Marrakech* (stimulus 1), *Fez II* (stimulus 2), *Fez I* (stimulus 3) and *Meknes* (stimulus 4) (note 3) We chose these four paintings because of their patterns with a central point, which can be used as a focus point (fig. 3). Because the colour combinations of *Fez I* and *Meknes* were too close to *Marrakech* and *Fez II*, we decided to combine the patterns of *Fez I* and *Meknes* with the colour combinations of two other paintings of the series which did not have a central focus point in their patterns: *Tetuan II* and *Rabat* (fig. 3).

[INSERT FIGURE 3 ABOUT HERE]

2.2.1. Target stimuli

To allow us to examine the unique roles of colour combination versus pattern, all 4 baseline colour combinations were combined with all 4 patterns, to come to a set of 16 target stimuli (fig. 4, the first row of each quadrant). 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.

Computer screens cannot show fluorescent colours, so all target stimuli had to be printed manually in their conventional and fluorescent variant in order to explore the effect of briefly exposing participants to conventional versus fluorescent colours. In preparation for the printing process, all designs were digitally replicated in *Vectorworks*, simulating the patterns of the paintings. To simulate the colour effects of the original artworks and in order to maximally avoid distractive factors (note 4) like texture, gloss and thickness, the designs were printed on large-scale paper (720 × 720 mm; 300 g Bristol). The fluorescent variants were screen-printed by the first author, using basic fluorescent inks (fluorescent yellow, fluorescent red, fluorescent orange, fluorescent green, fluorescent blue) of the brand *Publivenor* (note 5). The conventional variants were printed with an inkjet printer (quadri-colour) on the same paper, with colours that matched the reproductions (RGB without fluorescent effect measured from reproductions of the paintings) of these paintings (RGB-values of each conventional colour can be found in Appendix 1).

[INSERT FIGURE 4 ABOUT HERE]

2.2.2. Distractor stimuli

For each target stimulus, a larger stimulus space was created, from which distractor stimuli could be selected for each trial. The distractor stimuli consist of designs that differ in colour combination and/or pattern (each panel in Figure 4 represents a stimulus space, which includes the target stimuli on the first row). There are variations in how different the distractor stimuli are from the original target stimulus, and thus how difficult it will be to identify the correct target amongst these distractors. The stimulus space for a specific trial consists of 16 designs that can be described as follows:

a) *Target stimulus (n= 1).* The target stimulus consists of a specific colour combination and pattern. The target stimuli for this experiment are on the first row of each panel in Figure 4. Section 2.2.1 describes how these were created.

b) *Designs with the exact same colours, but a different pattern (n = 3).* These alternative designs have the same colours, but a pattern that could be any of the remaining (non-target) patterns selected for the experiment (straight cross: Fez I and Fez II; or diagonal cross: Marrakech and Meknes). These are the other three designs on the first row of each panel in Figure 4. (Note: these designs also function as target stimuli in other trials.)

c) *Designs with a different colour combination, but the exact same pattern (n = 3).* These designs have the same pattern as the target, but a different colour combination (so the designs in the same column, but a different row in the panel in Figure 4). All colour combinations were made up with alternative colours from the other target stimuli (blue, yellow, red, green, orange). We selected specific colours and combinations based on the distance the colour had from the alternative colour (calculated through deltaE, see Appendix 1) to allow for a comparable stimulus space per target stimulus in Figure 4.
   - One colour the same as the target, the other different, but relatively close to its replacement (deltaE between 38.28 and 63.44, see Appendix 1). This colour combination can be found in the second row for each panel in Figure 4.
   - One colour (the other colour than the one in the design above) the same as the target the other different, but relatively more removed from the original colour (deltaE between 118.28 and 141.52, see Appendix 1). This colour combination can be found in the third row for each panel in Figure 4.
   - Two colours different than the target. Here the two alternative colours from the above two designs were combined to create a new colour combination. This colour combination can be found in the fourth row for each panel in Figure 4.

d) Designs with a different colour combination and a different pattern (n = 9). These designs are a combination of the different patterns described in b) and the different colour combinations described in c).

Out of these 15 possible distractors for each target, 7 distractor stimuli were selected to accompany the target on the task screen for each trial (see Section 2.3.3). A semi-random allocation was used to select specific distractors: two designs were selected randomly from each row in the panels in Figure 4 (except for the first row, which already included the target and thus only one distractor design was selected). A constraint was further placed on the number of images that could be selected in a single column, which was fixed to two images. Under these conditions, each pattern and each colour combination occurred exactly twice.

2.3. Technical and logistic aspects of the experimental setup

Since the experiment could not be carried out as a traditional computer-based lab experiment (due to the main focus on fluorescent colours, which cannot be reproduced on a computer screen) , this section highlights the technical and logistic aspects of the experimental set-up. Afterwards, we will present the details of the procedure and task itself.

2.3.1. Experimental setup of material

The experimental setup is visualized in Figure 5. The first step in constructing the setup consisted of mounting a vertical formwork panel on top of a base panel that was fixed to the participant table. In the vertical panel, a square hole of 10 cm by 10 cm was made. Approximately 2 meters from the panel, an easel was placed on which prints could be mounted for display. An assistant was always present to help with changing the prints that were presented on the easel (see Section 2.3.2). On the other side of the panel, where the subject was seated, a chin rest was placed in such a way that a subject had a perfect view of the prints with both eyes through the square hole. A computer monitor was located to the right of the subject. Any interactions required from the subject occurred by manipulating a computer mouse. The experimenter was seated to the left of the subject and operated the control PC. This PC was running custom-developed software for monitoring the progress of the experiment (e.g. what print should be on display in the next upcoming trial), and in addition controlled what was present on the subject's monitor, as well as communicating with a microcontroller to operate the other hardware components of the setup. The experimental setup was placed in a corner office on the fourth floor, allowing sufficient natural light to be present in the room. The experiment took place during spring (April/May) on sunny days, between 11 a.m. and 5 p.m.

[INSERT FIGURE 5 ABOUT HERE]

2.3.2 Mechanical shutter

An unhoused Uniblitz VS-25 shutter (Vincent Associates) was fixed to a panel of Balsa wood material and attached to the top of the chin rest. Hook-and-loop fasteners were applied both to the vertical woodwork panel and the Balsa wood panel, which allowed to rotate the shutter so that it either covered the square opening in the woodwork (so subjects could only see what was behind when the shutter was open), or so that the opening was completely uncovered (fig. 6). When covering the square opening, the exact position of the shutter could further be adjusted to accommodate the location of the participant's dominant eye (this was determined and adjusted at the beginning of the session). In the open position, the aperture diameter was 25mm and was sufficient to see the whole print through one eye.

[INSERT FIGURE 6 ABOUT HERE]

During the experiment, the shutter was opened and closed by sending control signals to a VCM-D1 shutter driver (Vincent Associates). These signals were sent by an Arduino UNO Rev3 microcontroller, which was in turn controlled by the control PC. The shutter was operated in a normally-closed mode, which means that an activation signal needs to be present for the shutter to be opened. The duration of this activation signal determines how long the shutter will be opened. Activation signals of 3 ms, 6 ms, and 10 ms were used, which correspond to shutter opening times of 8 ms, 9 ms, 12 ms. This duration is measured from when the shutter is 50% open to the moment that the shutter is 50% closed.

2.3.3. Target prints mounted on easel

Target prints were presented on the easel (see fig. 5). Blocks of 8 prints could be mounted together on the easel, allowing for presenting the designs within this block in relatively quick succession, followed by a break within blocks, when the next block had to be mounted.
A block started with a research assistant placing the block of 8 prints (prepared beforehand) on the easel. A single trial started with the assistant uncovering the correct print on the easel. At that point, participants could not yet see the design, because the shutter was still closed. When everything was in place, the experimenter gave the signal that the trial was ready for presentation. The subject could then press a mouse button to initiate a series of three short beeps, after which the shutter was pulsed for the required exposure duration. Following shutter

closure, the response alternatives were displayed on the computer monitor on the right side of the participant. While waiting for a response, the assistant could already proceed with preparing the print for the next trial. After a response was collected, the same procedure was repeated. The subject was further allowed some rest between presentation blocks (when the assistant was mounting the new block).

2.4. Procedure and task

In this section, we outline the details of the task itself. Before the start of the experiment, the shutter was pulsed manually several times without any painting on the easel in order to make subjects familiar with the presentation procedure. After this, participants took part in two tasks: a short-exposure task (current article) and an after-image task (not discussed here).

The short-exposure task always followed the same procedure: Participants were first shortly exposed to one of the 32 available prints. After each exposure, they were subsequently confronted with a task screen on the computer, from which they had to identify the correct target stimulus (the computer-rendered analogue of the specific print they were exposed to) among 7 distractor stimuli (selected from the distractor set). Below, we outline the specifics of the task, including details on the presentation order, distractor selection, and task screen.

Before the start of the experiment all participants were asked to fill out a questionnaire (some standard demographic questions and some questions about aesthetic preferences and level of interest in art) and after the experiment all participants were asked to answer two questions about their aesthetic appreciation of the exposed stimuli (most preferred pattern and colour combination). After the short-exposure experiment (first part), participants were asked about their performance and whether they found some stimuli more difficult to target than others, and whether they noticed a colour difference among stimuli. Bearing in mind the quality of the self-referential nature of the paint as an important aspect of the study, the interviewer specifically noted when they spontaneously mentioned having seen fluorescent or intense colours and whether they experienced difficulties in finding the same colour combination among the distractors on the screen (more vague colours, mentioning to have seen other colours in the stimuli, etc.). In this paper, we only focus on the relevant aspects of the questionnaires. The entire procedure took about an hour per participant and the short-exposure experiment took about half an hour.

2.4.1. Exposure times and cycles

To explore exactly how 'instantaneous' the designs were, three different short exposure times were used in this experiment: 8 ms, 9 ms and 12 ms. (lower limit constrained by the mechanical shutter used, see Section 2.3.). Each participant did the task for all three exposure times, thus going through all 32 prints three times. In the remainder of the article, we will refer to one time going through all the prints as a 'cycle'. Thus, each participant goes through three cycles, with a different exposure time for each cycle. The order of the exposure times was randomized between participants, resulting in different numbers of participants per exposure time and cycle order (see Table 1).

Table 1

Number of participants per exposure time and cycle order

	8 ms	**9 ms**	**12 ms**
Cycle 1	14	13	13
Cycle 2	9	19	12
Cycle 3	17	8	15

2.4.2. Presentation order of target stimuli

Within each cycle, the 32 target prints were presented in 4 blocks of 8 prints each (fig. 7), related to the practical aspects of showing the prints on an easel (see Section 2.3 for details). The prints and order of prints within each block are therefore fixed. The order of the different blocks was randomized within each trial and over participants. Each block consists of 8 different designs, four conventional and four fluorescent versions. A conventional and fluorescent variant of the same design were never shown together in one block. For the counterbalancing of the blocks, we started from a sequence FCFFCFCC (F: fluorescent and C: conventional), in which we selected a random starting point.

[INSERT FIGURE 7 ABOUT HERE]

2.4.3. Selection of target among distractors

After each brief exposure to a target stimulus print, participants were presented with a computer screen (note 6) representing 8 different stimulus designs, one being the target and the other 7 distractor stimuli (see Section 2.2.2). Participants were asked to identify the correct design of the print they were presented with. Target and distractor stimuli were represented in a circle so that each stimulus had the same distance to the centre of the screen (see fig. 8 for an example). To allow us to compare performance for the fluorescent and conventional variants, the exact same distractors and presentation of distractors were shown for fluorescent and conventional variants of the same design.

[INSERT FIGURE 8 ABOUT HERE]

3. Results

In this section, results are discussed based on the research questions of the study. First, we explore how accurate participants are in identifying the correct design after seeing it for a very brief time, and thus focusing on the average 'instantaneousness' of the designs. We also explore whether this differs between the three exposure durations and whether there are learning effects over different cycles (Section 3.1). Second, we focus on the role of colour type (fluorescent or not), colour combination and pattern as predictors of the performance (Section 3.2). Third, following up on these results, we select a few designs of interest and explore the type of mistakes people made when they did not correctly identify the design (Section 3.3). Finally, we briefly approach the 'self-referential' claim related to fluorescent colours, by exploring our remarks about whether participants noticed to have seen fluorescent colours (Section 3.4).

Throughout the analyses, we work with model comparisons to compare models with our different predictors of interest and select the best fitting model. Specifically, given the repeated measures nature of the experiment (participants are repeatedly tested on the different designs), we work with generalized linear mixed-effect models, specifying the binomial nature (correct/false, with a chance level of 1/8) of the outcome and always adding a random intercept per participant. The statistical software R is used, with the 'glmer' function of the package 'lme4' to fit the different models. Models are compared using the AIC and BIC information criteria, to explore how well the model fits the data while considering (and penalizing) the number of predictors. The lower the AIC and BIC numbers, the better this balance is for the specific model.

3.1. Are the designs based on Frank Stella's Moroccan paintings experienced 'instantaneously'?

On average, participants performed very well in identifying the correct design among distractors. Overall performance of participants ranged between 67.71% - 98.96%, with an average of 86.43% (SD = 9.06%)

3.1.1 Exposure time and learning effects

Participants saw all 32 prints three times, once for each exposure duration (8, 9, 12 ms), with the order of exposure durations differing between participants (see Table 1). Here, we are interested in finding out the effect of exposure duration, but we also explored whether there is a role of cycle number to see whether a learning effect took place as participants got more acquainted with the prints and designs. Figure 9 shows boxplots of the performance of participants for each combination of cycle number and exposure duration.

[INSERT FIGURE 9 ABOUT HERE]

Different general linear models (binomial distribution) were compared to explore the role of these two variables and their interaction in predicting trial outcomes (correct or incorrect). Due to the multilevel structure of the data, all models included a random effect for each participant. A comparison of information criteria (AIC and BIC) showed that a model with only cycle number as main effect performs best, indicating there is a performance difference as participants progress through the cycles. Specifically, performance is increasing over different cycles (first cycle: M = 79.77%; SD = 13.78; second cycle: M = 88.20%, SD = 9.84; and third cycle: M = 91.33%; SD = 8.74), indicating a learning effect over different cycles.

Table 2

Model comparison of general linear mixed effect models with binomial distribution.

	df	**AIC**	**BIC**

No fixed effect	2	2902.0	2914.5
Cycle number	4	**2824.2**	**2849.2**
Exposure duration	4	2900.1	2925.1
Cycle number + Exposure duration	6	2825.3	2862.9
Cycle number + Exposure duration + Cycle number * Exposure duration	10	2826.4	2888.9

Note: All models have a random effect for participant (random intercept) to consider the multilevel structure of the data.

Given the high average performance levels for the second and third cycles (ceiling effect), we decided to focus on the first cycle only throughout the remainder of the article. This gives us the best insight into participants' first initial reactions to the designs, as well as give us more variance in performance to allow to study the differences between different designs and conventional versus fluorescent colours in the next sections.

3.2. The role of fluorescence, colour combination and pattern in 'instantaneousness' of the designs

In the previous section, we found that participants were generally very good in identifying the correct design among distractors, highlighting the 'instantaneous' nature of the designs. Here, we want to explore whether there is a difference between fluorescent and conventional designs, as well as explore the role of specific colour combinations and patterns in predicting participants performance in the first cycle of the experiment.

3.2.1 Average difference between conventional and fluorescent variants

Boxplots for participants' performance of fluorescent versus conventional designs are shown in Figure 10. Again, model comparisons for general linear mixed effect models were used to explore the difference statistically (Table 3). Adding the type of design as a fixed effect did not improve the fit of a model with only a random effect per participant, indicating that overall there is not much difference in performance between fluorescent and conventional variants of a design.

[INSERT FIGURE 10 ABOUT HERE]

Table 3

Model comparison of general linear mixed effect models with binomial distribution.

	df	AIC	BIC
Random intercept model	2	**1238.8**	**1249.1**
Adding fluorescent effect	3	1240.1	1255.6

Note: All models have a random effect for participant (random intercept) to consider the multilevel structure of the data and are tested on the data of cycle 1.

3.2.2 Exploring specific designs: The role of fluorescence in combination with colour combination and pattern

In the previous section, we found that there were no overall differences for fluorescent versus conventional colours. Here we aim to go more into depth, by examining whether there are effects of the other aspects of the designs (colour combination and pattern), and whether these interact with each other or with the fluorescent colours.

Again, we used model comparison to find the model with the best combination of fit and sparseness. We tested all combinations of the predictor's fluorescent, colour and pattern (main effects, two-way interactions, three-way interactions). Table 4 shows the resulting statistics. Comparing AIC and BIC criteria of all the models, two different models produce the best result, depending on the criteria that are chosen. Whereas the AIC criteria favour a model with an interaction between fluorescence and colour and a main effect of pattern; the BIC criteria favour the model with only pattern as a main effect.

Comparing these two specific (nested) models with the chi-square difference test favours the more complex model (Fluorescent * Colour + Pattern), over the simpler model (Pattern) (χ^2 = 35.89, df =7, p <.0001). Given this outcome, as well as our theoretical interest in the role of fluorescence, we will further elaborate on the complex model (Fluorescent*Colour + Pattern) and interpret both the effect of pattern, as well as the interaction between colour and fluorescence. Figure 11 shows the plots for these two effects.

Concerning the main effect of pattern (fig. 11A), it seems that designs with the fourth pattern (diagonal cross with horizontal lines on top and bottom, and vertical lines on the sides) result in higher performance levels in participants compared to the other three patterns.

When examining the interaction effect between fluorescence and colour (fig. 11B), the main difference seems to lie in the green-orange and red-yellow designs. Designs with green-orange colours show higher performance for conventional colours, whereas the opposite is found for red-yellow designs, where a higher performance is reached for fluorescent colours.

Appendix 2 shows an overview table with average performance levels for each specific design.

Table 4.

Model comparison of general linear mixed effect models with binomial distribution.

	df	**AIC**	**BIC**
Random intercept model	2	1238.8	1249.1
Fluorescent	3	1240.2	1255.7
Colour	5	1232.8	1258.6
Pattern	5	1215.3	**1241.1**
Fluorescent + Colour	6	1234.3	1265.2
Fluorescent + Pattern	6	1216.8	1247.7
Colour + Pattern	8	1209.1	1250.3
Fluorescent + Colour + Pattern	9	1210.6	1257.0
Fluorescent * Colour	9	1217.8	1264.2
Fluorescent * Pattern	9	1219.3	1265.7
Colour * Pattern	17	1214.3	1301.9
Fluorescent * Colour + Pattern	12	**1193.4**	1255.3
Fluorescent * Pattern + Colour	12	1213.1	1275.0
Colour * Pattern + Fluorescent	18	1215.8	1308.6
Fluorescent * pattern * colour	33	1214.0	1384.1

Notes: All models have a random effect for participant (random intercept) to consider the multilevel structure of the data and are tested on the data of cycle 1. All combinations of the predictors fluorescence, colour combination and pattern are tested.

[INSERT FIGURE 11 ABOUT HERE]

3.3. Type of mistakes made for green-orange and red-yellow designs

In the previous section, we found that there was an interaction between fluorescence and colour, and that the main differences between fluorescent and conventional variants were found for green-orange designs (conventional higher performance) and red-yellow designs (fluorescence higher performance).

In this section, we aim to explore further what caused these differences, by exploring what type of mistakes were made when participants did not identify the correct target. In doing this, we aim to find out whether participants were mainly confused by pattern, colour or both when they made mistakes in identifying the target; and whether this differs between fluorescent and conventional variants.

3.3.1 Type per mistake per colour type for green-orange (cycle 1)

As mentioned above, participants made more mistakes in cycle 1 for the fluorescent variants of the green-orange designs. In Figure 12 we see that the number of ‘pattern only’ mistakes is the same in both fluorescent and conventional variants (n = 12), but for fluorescent colours there are more ‘colour only’ mistakes (fluorescent n mistakes = 8; conventional n mistakes = 4), and especially errors with a combination of both colour and pattern (fluorescent n mistakes = 21; conventional n mistakes = 8).

[INSERT FIGURE 12 ABOUT HERE]

3.3.2 Type of mistake per colour type for red-yellow (cycle 1)

As mentioned above, participants made more mistakes in cycle 1 for the conventional variants of the red-yellow designs. In Figure 13 we see that the number of mistakes of both pattern and colour is very similar in both fluorescent and conventional variants (fluorescent n mistakes = 6; conventional n mistakes = 7), but for conventional colours there are slightly more 'colour only' mistakes (fluorescent n mistakes = 4; conventional n mistakes = 2), but especially many more 'pattern only' mistakes (fluorescent n mistakes = 7; conventional n mistakes = 32).

[INSERT FIGURE 13 ABOUT HERE]

3.4. Are fluorescent colours self-referential?

Finally, our last research question focused on the self-referential quality of the paintings. From the information we gathered through interviews after the short-exposure experiment, we can conclude that most of the subjects did not mention the use of fluorescent colours. Only 8 participants remarked about a difference in the colour types of the stimuli they saw, of which only 3 defined them as fluorescent, whereas the other 5 indicated to have seen different, more intense or vague colours, without mentioning that they saw fluorescent colours.

4. Discussion and Conclusion

This study has examined the instantaneous quality of Frank Stella's Moroccan paintings, in which we focussed on the extent to which his use of fluorescent colours influenced the 'capturing-time' of the images. We developed this study by taking the phenomenological observations that functioned as concepts in the art theoretical discourse as our starting point. By testing whether these (fluorescent) paintings can be seen after short exposure times, we gathered new information which will function in the re-evaluation of Stella's artistic intuitions and the artworks' related art criticism.

Overall, the general performance was very high, which indicated that the patterns and colours seemed easy to grasp, even among difficult distractors and for very short exposure durations (8, 9 and 12 ms). All participants completed three cycles, in which they saw all designs, each time with a different shutter opening duration (8, 9 or 12 ms, order randomized over participants). Exploring the role of exposure duration (8, 9 or 12 ms) and cycle index (first, second or third cycle of all designs), it seemed that mainly cycle index (irrespective of shutter duration) seemed to predict participants performance. This indicates a learning effect, where participants' performance improved as they got to see the same designs again in the second and third cycles (where participants are getting very close to perfect performance). Given the ceiling effects in the later cycles, we decided to focus mainly on performance in the first cycle, but even in this first cycle, general performance was high (M = 79.77%; SD = 13.78). It is possible that future research, using even shorter exposure durations, could result in more pronounced effects for variables of interest (fluorescence, colour, pattern) as there would be more mistakes and variance to explain. In this study, however, we could not get any faster shutter durations, because of our specific mechanical shutter.

Focusing on participants' performance during the first cycle, we found no general differences in colour type (fluorescent vs. conventional colours), which was against our expectations. However, when exploring fluorescence in combination with other aspects of the design (colour combination and pattern), we did find two effects that seemed to predict performance. First, performance seemed to depend on specific design patterns: both patterns with a diagonal cross and horizontal lines on top/bottom and vertical lines on the sides (stimulus 1, based on *Marrakech* and stimulus 4 based on *Meknes*) appeared to be the easiest to grasp.

Second, fluorescence seemed to interact with specific colour combinations in predicting performance. Specifically, whereas the green-orange designs showed a better performance for conventional variants than fluorescent variants, the opposite was found for red-yellow designs. Further exploration of the type of mistakes made in these cases revealed that for the green-orange designs, more mistakes of both colour and pattern were made in the fluorescent as compared to the conventional type. Thus, participants seemed to be more confused with both colour and pattern for the fluorescent types. For the red-yellow designs, there seemed to be more pattern mistakes in the conventional types as compared to the fluorescent types. Thus, the lower performance for conventional types in these designs can be explained by confusion about the specific pattern.

Given the exploratory nature of these follow-up analyses and the scarce studies on these specific differences between fluorescent and conventional colours, we did not have specific hypotheses about these nuanced findings. However, we do have a few possible explanations for our outcomes.

First, when it comes to the specific differences between fluorescent and conventional variants for green-orange and red-yellow designs, we explored whether contrast differences in luminance between the two colours of each colour combination might explain part of the results. The figure below (fig. 14) shows the contrast differences for all the colour combinations for both conventional and fluorescent versions. Whereas, in general, the contrast difference is higher for fluorescent variants, for the green/orange combination, it is lower in the fluorescent versions and is generally low contrast. After short exposure, the low amount of contrast might have caused colour confusion and/or optical vibration, especially in the fluorescent versions, which might have also complicated the visibility of the pattern. The transparent character of the fluorescent paints might have strengthened this effect.

[INSERT FIGURE 14 ABOUT HERE]

Another alternative explanation points towards a possible limitation in our paradigm, as well as the general reproduction problem of fluorescent colours. Even though we showed people the true fluorescent designs (handmade paintings), we did ask them to select the correct design among distractors on a computer screen. It might be that some errors are due to confusion when trying to target the fluorescent colour in its conventional colour as rendered on a computer screen, which did not exactly fit the appearance of the fluorescent colours (e.g. some subjects mistook the fluorescent red colour for an orange when they selected a distractor). Conventional displays cannot usually display fluorescent colours properly. It might be that this colour confusion was particularly pronounced for the green-orange designs and that this caused the lower performance rate for fluorescent colours for these designs. Moreover, the same possible confusion might also explain why we did not find any general effects of fluorescent colour versus conventional colours. It could still be that the fluorescent colours were more instantaneous, but this effect might have been watered down by the confusion between real fluorescent colours and selecting the identified matches on a conventional screen. We are aware of this problem, but unfortunately, it was practically almost impossible to work with paper versions for the choice stimuli, not only because a huge amount of hand-printed combinations of targets and distractors would have to be made but also because manually changing them on a trial-by-trial basis would have slowed the experiment down too much.

Finally, when it comes to the 'self-referential' nature of fluorescent colours, it was interesting to observe that most participants (80%) did not spontaneously mention to have seen the fluorescent effect of the colours, even when they were specifically asked by the interviewer whether they noticed any differences in the colours. This can also indicate that the fluorescent effect at these shorter exposure times was not striking enough to make a spontaneous comment about it. Further research is needed to determine whether participants can detect and perceive differences between conventional and fluorescent colours during such short exposure times. This would provide more insight into the claims about self-referentiality.

Although the outcome of this study highlights only part of the total experience of these types of paintings, when holding the insights against the light of the art criticism we can conclude that, although the pattern and colours can be detected instantaneously, it might be that the self-referential quality of the paints can only be experienced after longer viewing. However, the question whether a participant can instantly have a twofoldness experience when observing Stella's work requires more research, perhaps through another experiment in which a real painting is exposed for a short amount of time after which participants could be questioned about their visual experiences (Do they spontaneously experience nuances of the materiality of the surface, can they identify the fluorescent colours or do they only see the depicted image?). It would also be interesting to better determine the amount of time participants need to experience both (or in this case, to detect fluorescent colours). Further, Stella's formula for 'instantaneous' paintings is not identical for different combinations. From our data it seems to be that fluorescence might also have different effects depending on the specific colours, causing some patterns and colour combinations easier to grasp than others, without leading to an overall fluorescence advantage. To indicate within the broader oeuvre of Stella to what extent this series of fluorescent paintings are more instantaneous than his other series (Black Paintings, Aluminum, and Copper paintings), more tests should be done with various colours and types of paint.

Even though we cannot draw any big conclusions on the effects of fluorescent colours in the paintings of Stella in general, we do believe this study highlights the importance of putting in continuous effort in trying to design experiments where viewers are tested in conditions that are more aligned with actual nature of the artworks. The importance of this is crucial both for the field of empirical aesthetics, as well as the field of art criticism.

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Notes

1. Examples of Stella's sketches can be found on the website of MoMa: https://www.moma.org/collection/works/38530?artist_id=5640&locale=en&page=1&sov_referrer=artist
2. To conduct the Ishihara test we used an app (i.e., Color Blindness Test) on an Android tablet.
3. Although the names represent unique works, they will be used throughout this paper to refer to the specific pattern that is present in an image (see columns in fig. 3).
4. The original paintings have a small line of bare canvas in between the stripes. At this stage, because of the complexity of the test, we decided to leave out this detail to eliminate further distractors, so we could focus on the comparison of the pattern and colour combinations. Also, the impact of the size and viewing distance were not considered in this study.
5. Colour-match numbers of each used fluorescent silkscreen ink of the brand *Publivenor*: red: FL 201; yellow: FL 101; Blue: FL 301; green: FL 401; pink: FL 241. All conventional colours were mixed using the following colour-match numbers: yellow: 106; red: 210; blue: 300. To add white, we used *printperfect Lac FF New*.
6. Note that, opposed to the printed version of the target designs, the task screen itself is on a computer screen (due to practical limitations of screen printing all possible task screens on paper). As a result, the task screen will only show conventional colours (as fluorescent colours cannot be presented on a computer screen).

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Figure Captions

Figure 1. Marrakech (from Frank Stella's Moroccan series), fluorescent (red and yellow) alkyd housepaint on unprimed cotton canvas (2m x 2m). Source: Photograph by De Winter, Art © Frank Stella (© SABAM Belgium 2019)

Figure 2. Day-Glo commercial: How do you measure the Day-Glo difference? from Day-Glo, n.d. (http://www.dayglo.com/fileshare/pdf/TelcomStudy-Summary.pdf). ©Day-Glo

Figure 3. Design of 4 stimuli: Marrakech (stimulus 1), Fez II (stimulus 2) have the same pattern and colour combination of the original paintings. Fez I (stimulus 3) and Meknes (stimulus 4) are a combination of the patterns of Fez I and Meknes with the colours from Tetuan II and Rabat. All these paintings are from Frank Stella's Moroccan series. All paintings exist of fluorescent alkyd housepaint on unprimed cotton canvas (2m x 2m). Art © Frank Stella (© SABAM Belgium 2019)

Figure 4. Image groups used in the experiment. In each quadrant, the first row represents the 16 images (4 colours x 4 patterns) that were also hand crafted and presented to the subject through the shutter system. Response alternatives for a given hand crafted image were sampled from the quadrant to which the image belonged according to the procedures described in text.

Figure 5. Plan view of the experimental setup. The subject (B) was seated in front of a vertical panel (1), in which an opening was made to view an easel (2) on which prints could be mounted for display. A central control computer (PC) allowed the experimenter (A) to monitor the progress of the experiment on one monitor (3b), and presented response screens to the subject on a second monitor (3a). Furthermore, the experimental software was used to interact with an Arduino microcontroller (4), which could send control signals to either the shutter driver (4a) or the motor control unit(4b).

Figure 6. Setup from the point of view of the subject. In the experiment, the shutter panel could be rotated so that the scene behind the panel was only visible through the aperture (left).

Figure 7. Four different blocks (A, B, C, and D). Within each block, grey lines surrounding the image are used here to represent fluorescent patterns.

Figure 8. Example of the task screen on a computer screen. Participants have to select the correct target stimulus (the one they were briefly exposed to) among distractor stimuli.

Figure 9. Boxplots of the performance of participants in each combination of cycle number (x-axis) and exposure duration (legend). The y-axis shows the percentage of correctly identifying the correct target design. The horizontal line shows the chance level for our study design (1/8 = 12.5%).

Figure 10. Boxplots of the performance of participants for fluorescent and conventional variants during cycle 1 (x-axis). The y-axis shows the percentage of correctly identifying the correct target design. The horizontal line shows the chance level for our study design (1/8 = 12.5%)

Figure 11. Effect plots for the model selected through the model comparison for cycle 1 data. A: Main effect of pattern, B: Interaction between fluorescence and colour type. Effect estimates are shown, together with an error bar indicating the lower and upper limits of the confidence interval of the effect.

Figure 12. Number of mistakes made in cycle 1 for green-orange designs of conventional and fluorescent variants, separated by type of mistake (pattern-only; colour-only; both).

Figure 13. Number of mistakes made in cycle 1 for yellow-red designs of conventional and fluorescent variants, separated by type of mistake (pattern-only; colour-only; both).

Figure 14. Mean luminance distance between design colours per colour type

Appendix 1

Delta E calculation for each stimulus distractor (http://colormine.org/delta-e-calculator/)

stimulus 1	**RGB**	**distractor 1 (D1)**	**RGB**	**DeltaE**
yellow	247%, 239%, 79%	orange	255%, 128%, 0%	**63.4447**
blue	55%, 131%, 247%	blue	55%, 131%, 247%	idem
		distractor 2 (D2)		
yellow		yellow	247%, 239%, 79%	idem
blue		green	0%, 128%, 0%	**133.8472**
		distractor 3 (D3)		
yellow		green	0%, 128%, 0%	**63.9156**
blue		orange	255%, 128%, 0%	**141.5224**
stimulus 2		**distractor 1 (D1)**		
yellow	247%, 239%, 79%	green	0%, 128%, 0%	**63.9156**
red	229%, 50%, 41%	red	229%, 50%, 41%	idem
		distractor 2 (D2)		
yellow		yellow	247%, 239%, 79%	idem
red		green	0%, 128%, 0%	**118.2766**
		distractor 3 (D3)		
yellow		orange	255%, 128%, 0%	**63.4447**
red		blue	55%, 131%, 247%	**123.819**
stimulus 3		**distractor 1 (D1)**		
orange	255%, 128%, 0%	yellow	247%, 239%, 79%	**63.4447**
green	0%, 128%, 0%	green	0%, 128%, 0%	idem
		distractor 2 (D2)		
orange		orange	255%, 128%, 0%	idem

green		red	229%, 50%, 41%	**118.2766**
		distractor 3 (D3)		
orange		yellow	247%, 239%, 79%	**63.4447**
green		blue	55%, 131%, 247%	**133.8472**
stimulus 4		**distractor 1 (D1)**		
red	229%, 50%, 41%	red	229%, 50%, 41%	idem
blue	55%, 131%, 247%	green	0%, 128%, 0%	**133.8472**
		distractor 2 (D2)		
red		orange	255%, 128%, 0%	**38.2767**
blue		blue	55%, 131%, 247%	idem
		distractor 3 (D3)		
red		orange	255%, 128%, 0%	**38.2767**
blue		green	0%, 128%, 0%	**133.8472**

Appendix 2

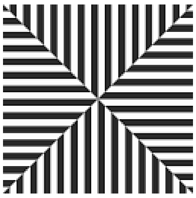
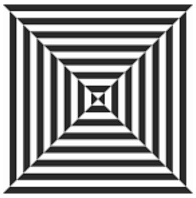
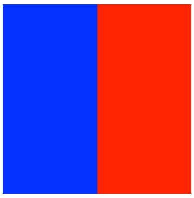
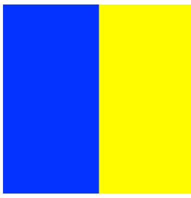
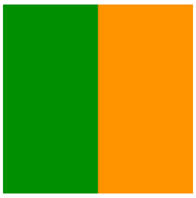
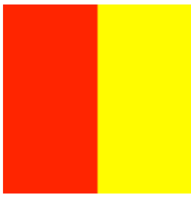
	Pattern 1 	Pattern 2 	Pattern 3 	Pattern 4 	
Blue-Red 	C: 57.5% F: 70.0%	C: 80.0% F: 80.0%	C: 65.0% F: 75.0%	C: 87.5% F: 75.0%	C: 72.50% F: 75.00%
Blue-Yellow 	C: 80.0% F: 77.5%	C: 85.0% F: 82.5%	C: 77.5% F: 77.5%	C: 95.0% F: 95.0%	C: 84.38% F: 83.13%
Green-Orange 	C: 77.5% F: 70.0%	C: 87.5% F: 70.0%	C: 77.5% F: 70.0%	C: 97.5% F: 87.5%	C: 85.00% F: 74.38%
Red-Yellow 	C: 72.5% F: 92.5%	C: 62.5% F: 87.5%	C: 75.0% F: 90.0%	C: 85.0% F: 90.0%	C: 73.75% F: 90.00%
	C: 71.88% F: 77.50%	C: 78.75% F: 80.00%	C: 73.75% F: 78.13%	C: 91.25% F: 83.88%	

Figure 15. Overview of percentage correct per combination of colour, pattern and colour type (fluorescent versus conventional) in cycle 1.

Figure 1

Click here to access/download;Figure;fig_1.tiff

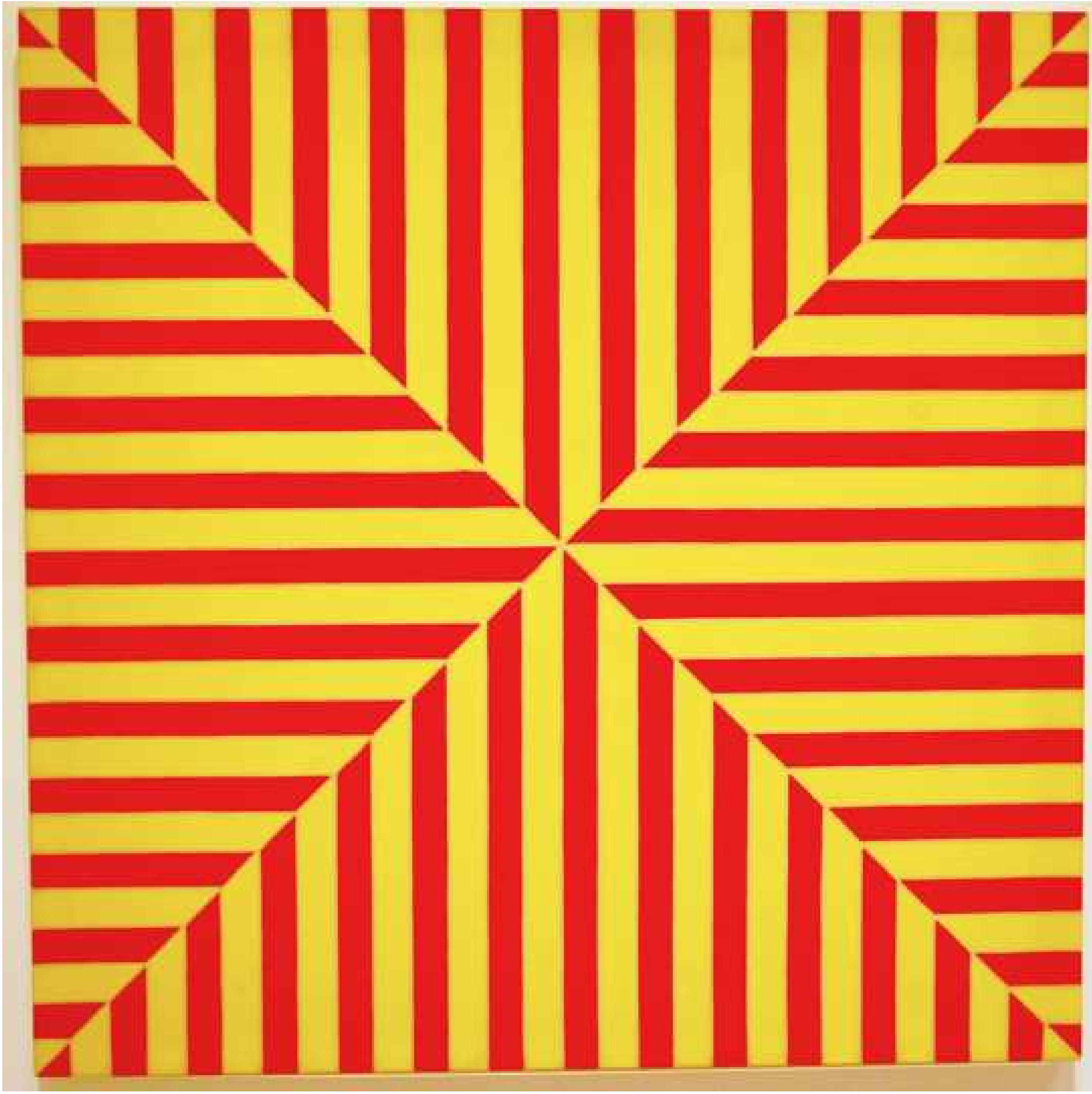


Figure 2

Click here to access/download;Figure;fig_2.tiff

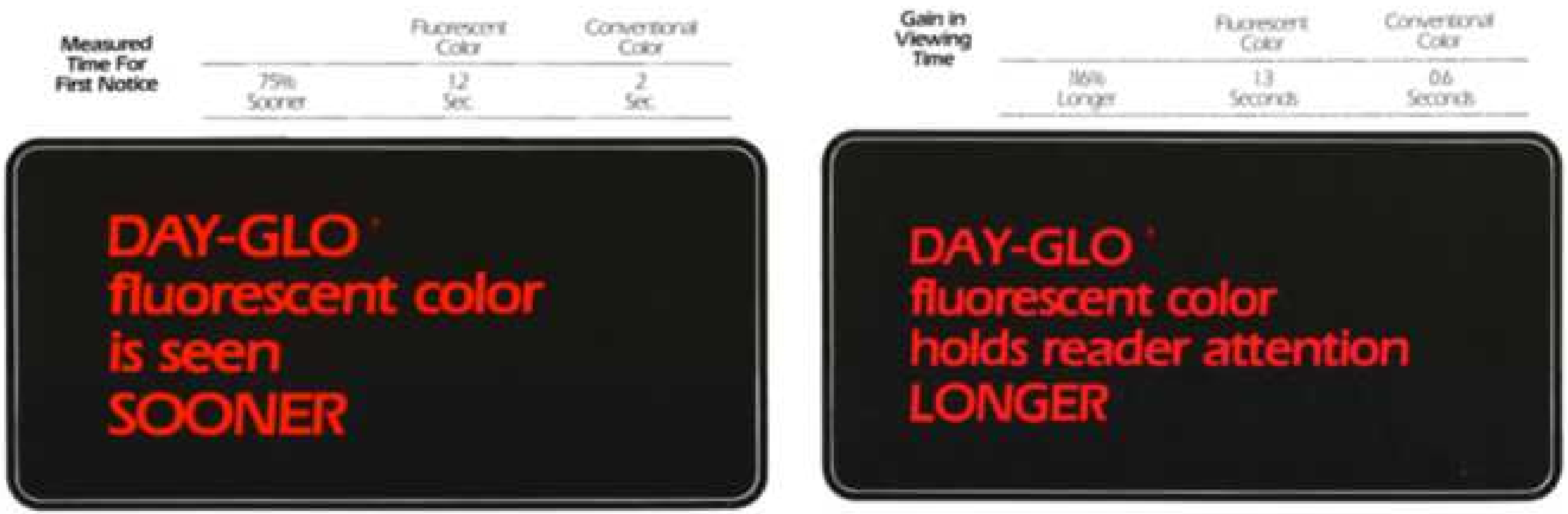


Figure 3

Click here to access/download;Figure;fig_3.tiff

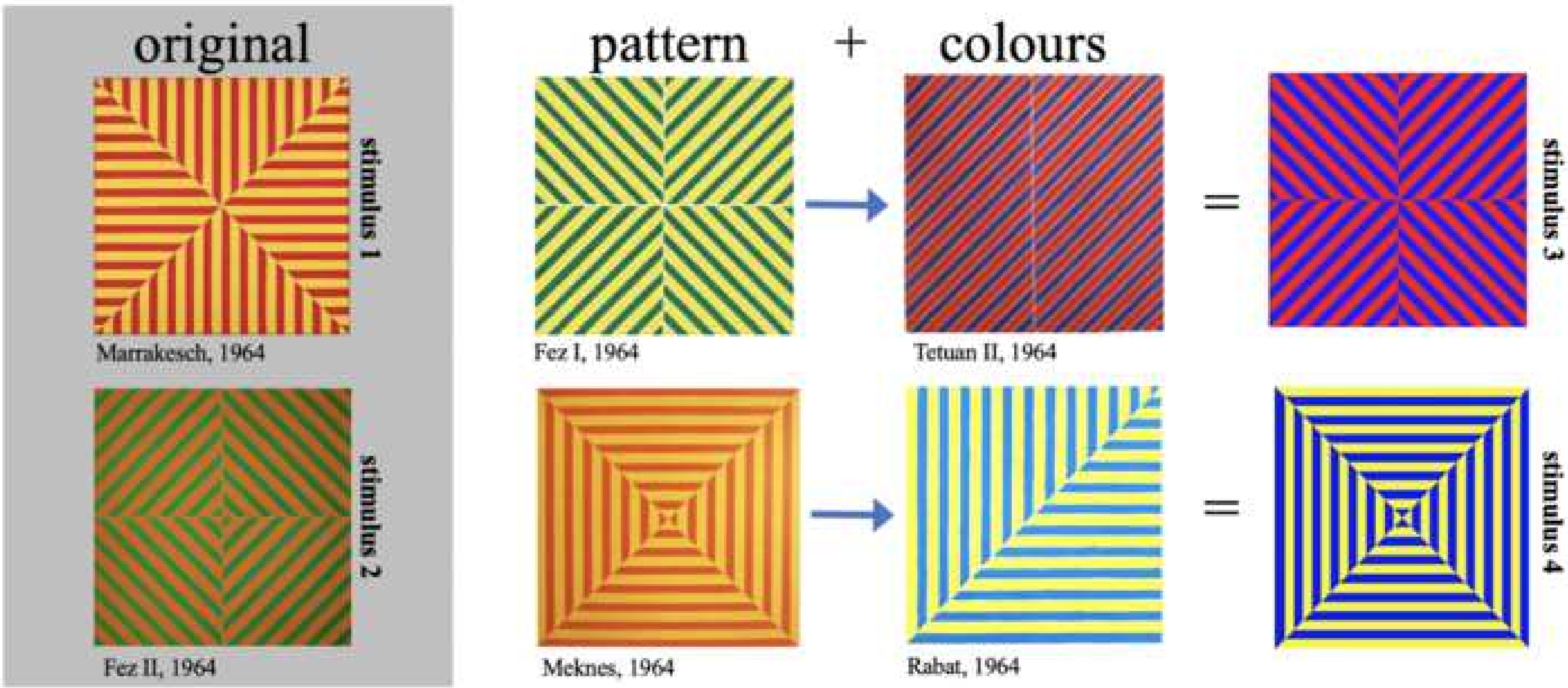


Figure 4

Click here to access/download;Figure;fig_4.tiff

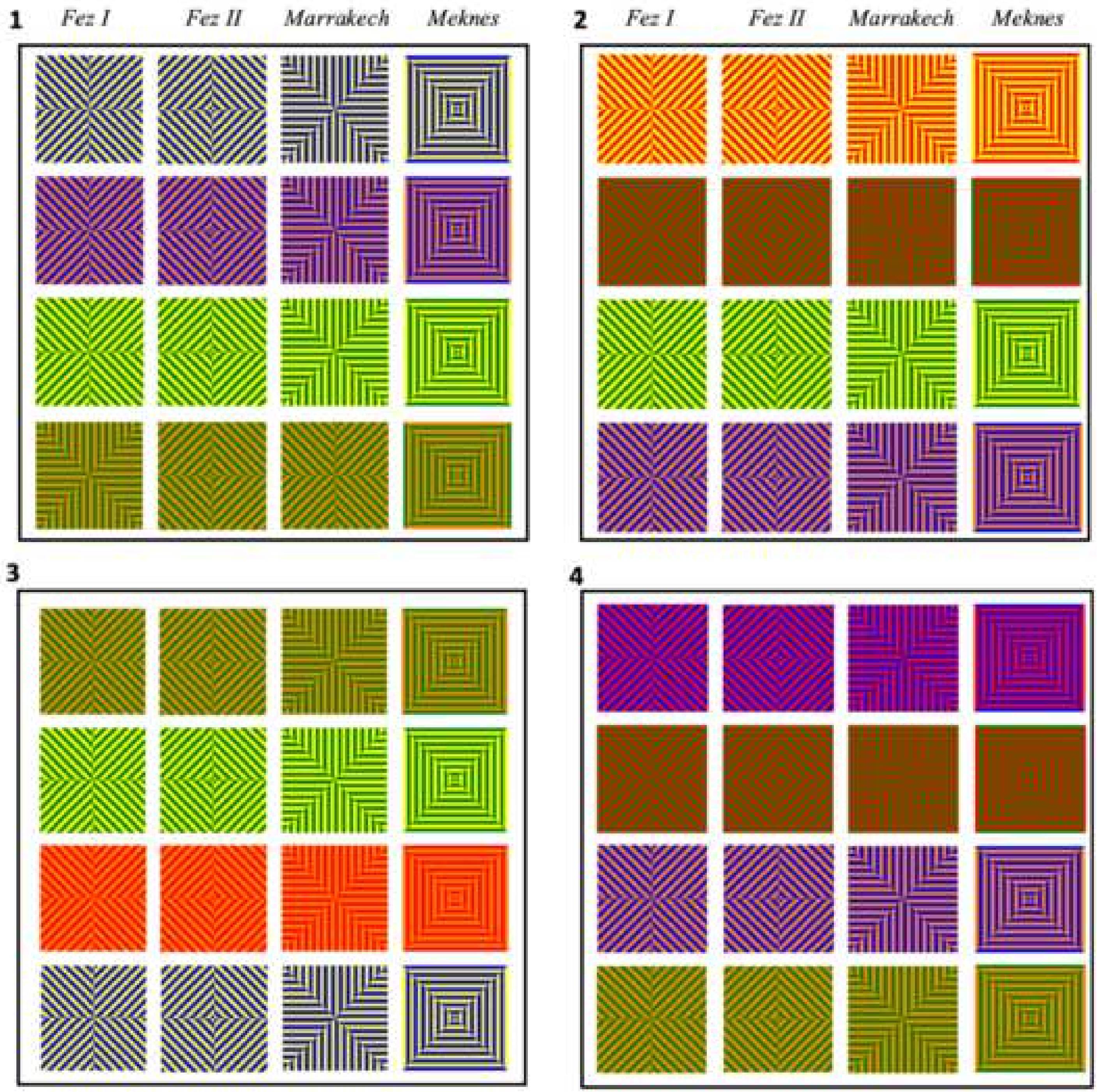
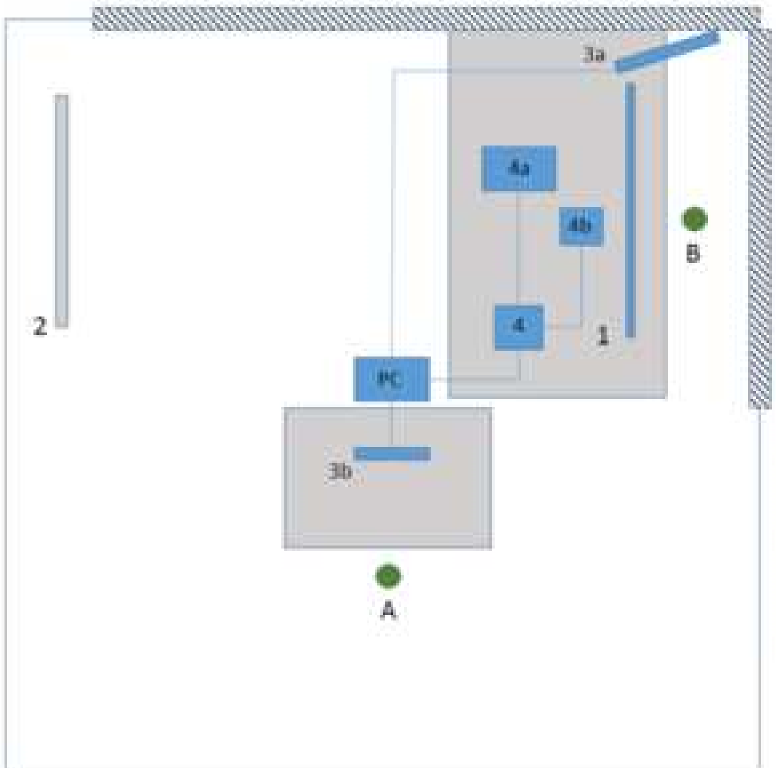


Figure 5

Click here to access/download;Figure;fig_5.tiff



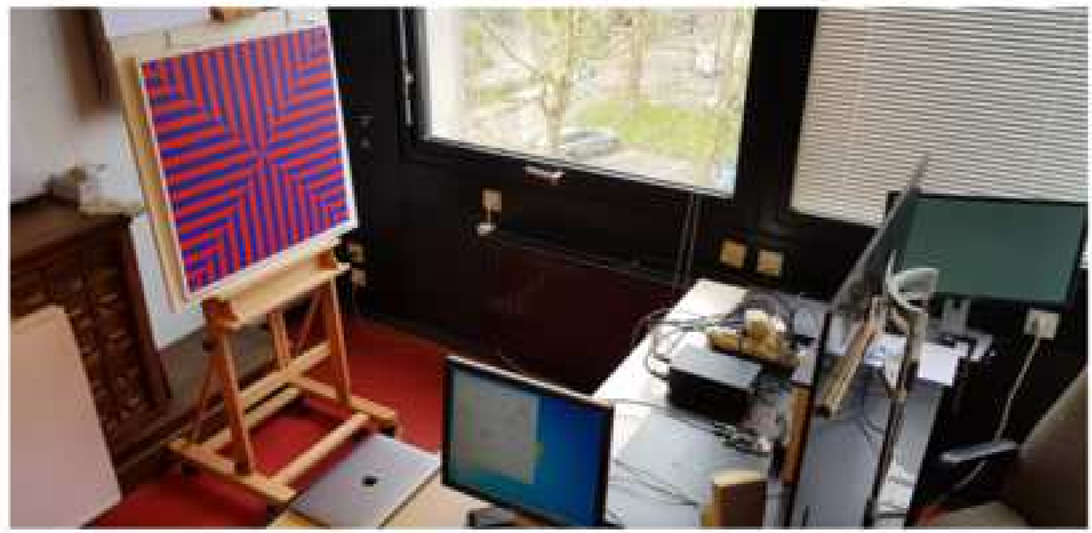


Figure 6

Click here to access/download;Figure;fig_6.tiff

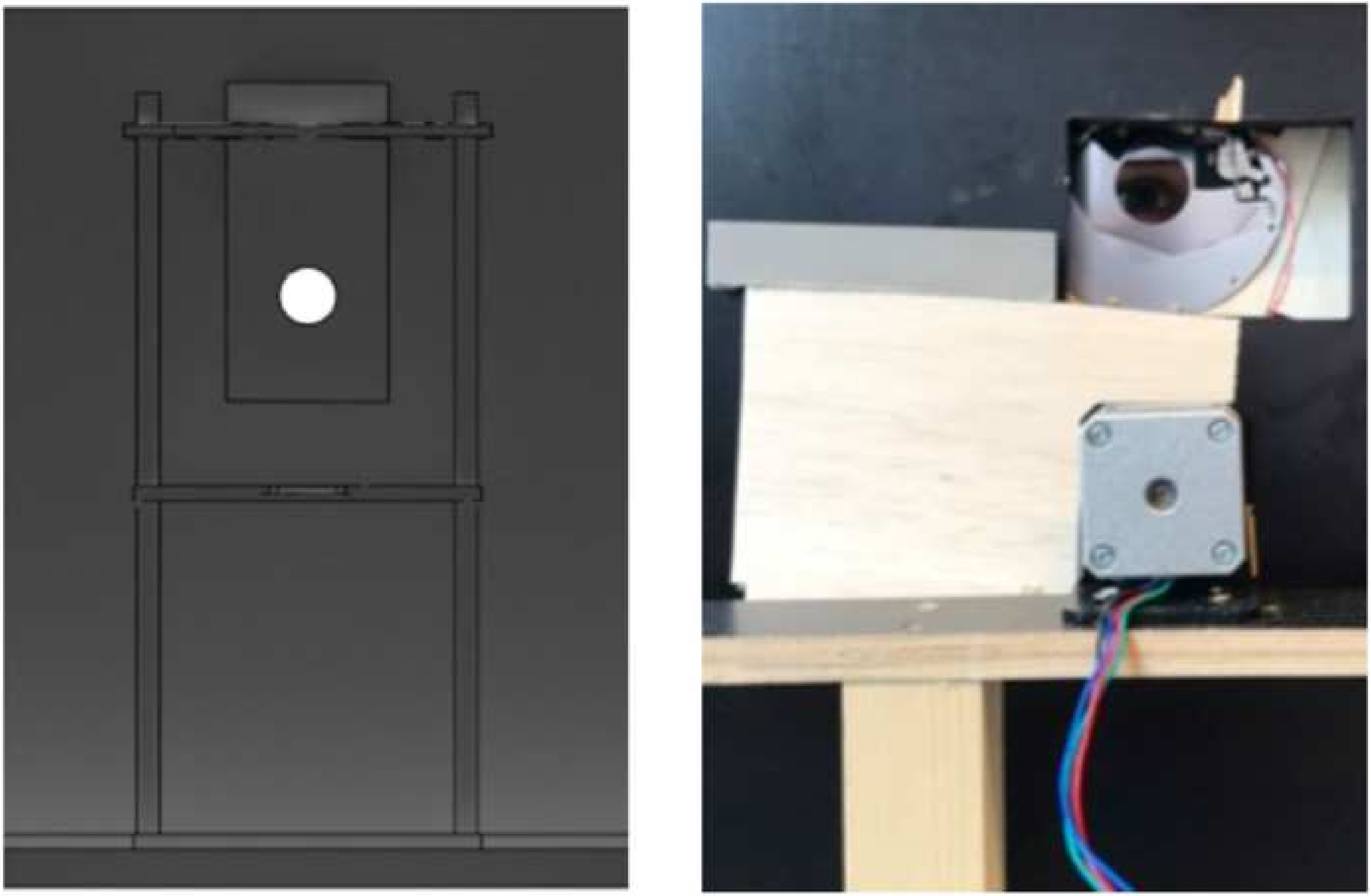


Figure 7

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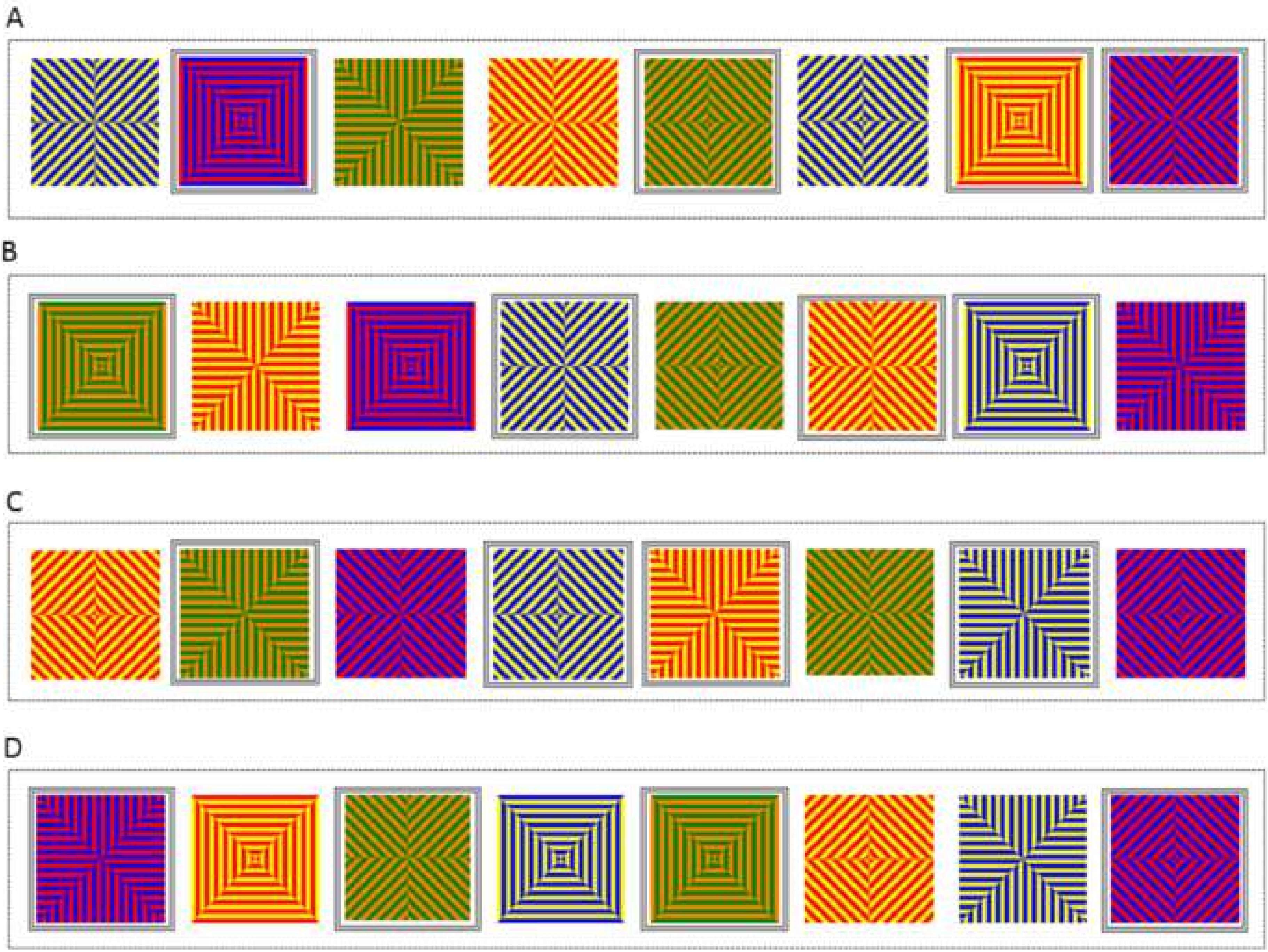

Figure 8

Click here to access/download;Figure;fig_8.tiff

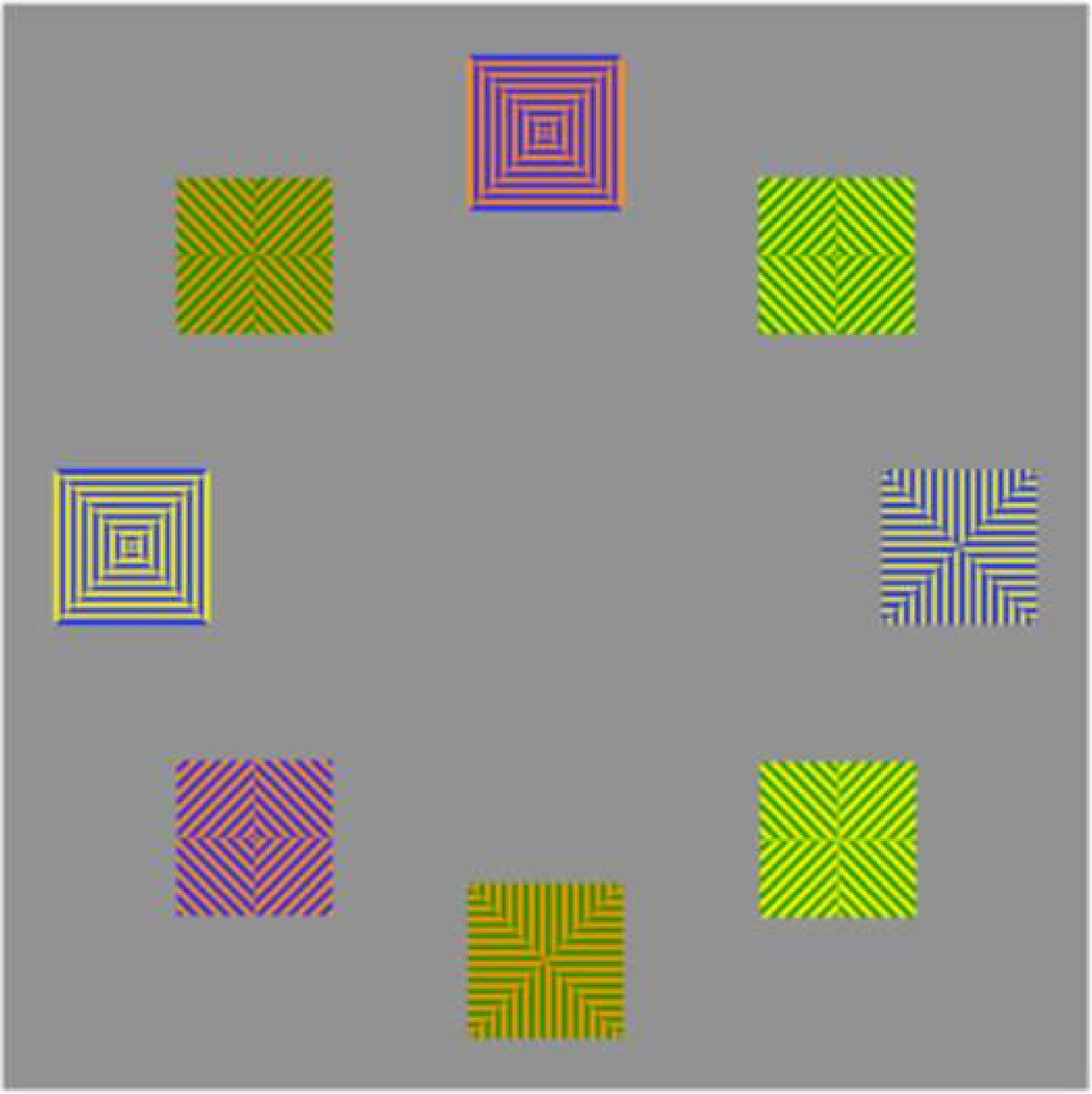

Figure 9

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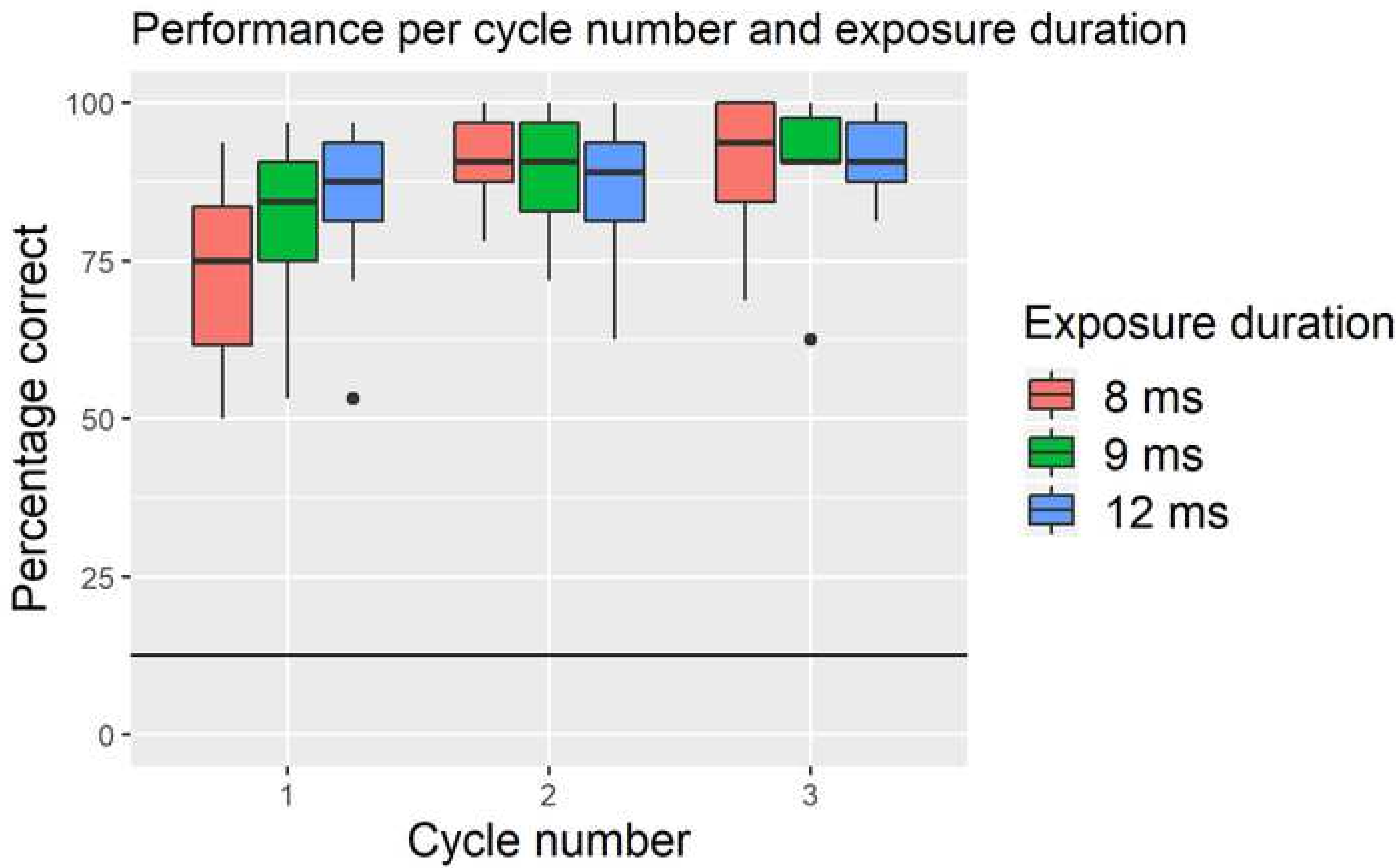

Figure 10

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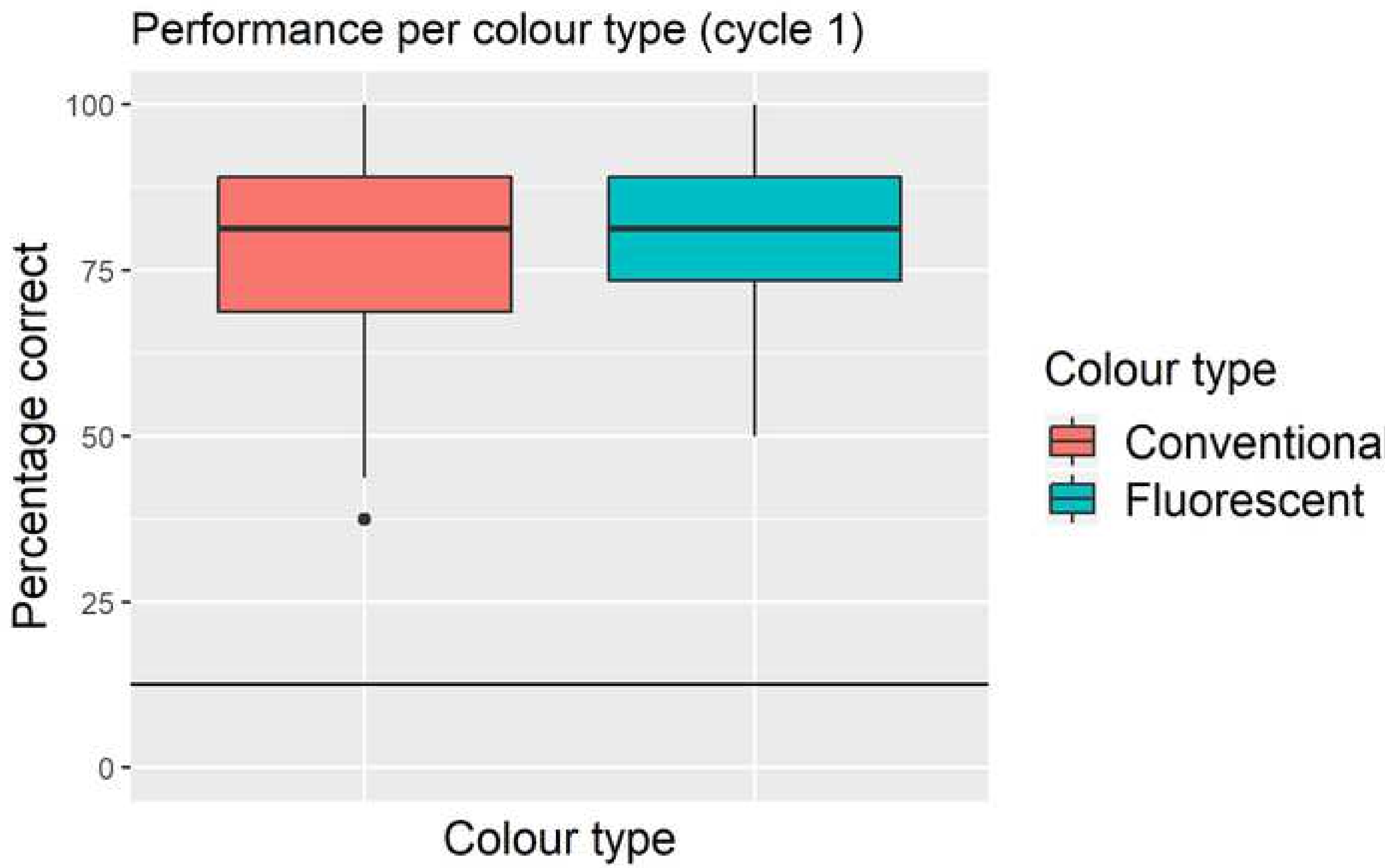

Figure 11

Click here to access/download;Figure;fig_11.tiff

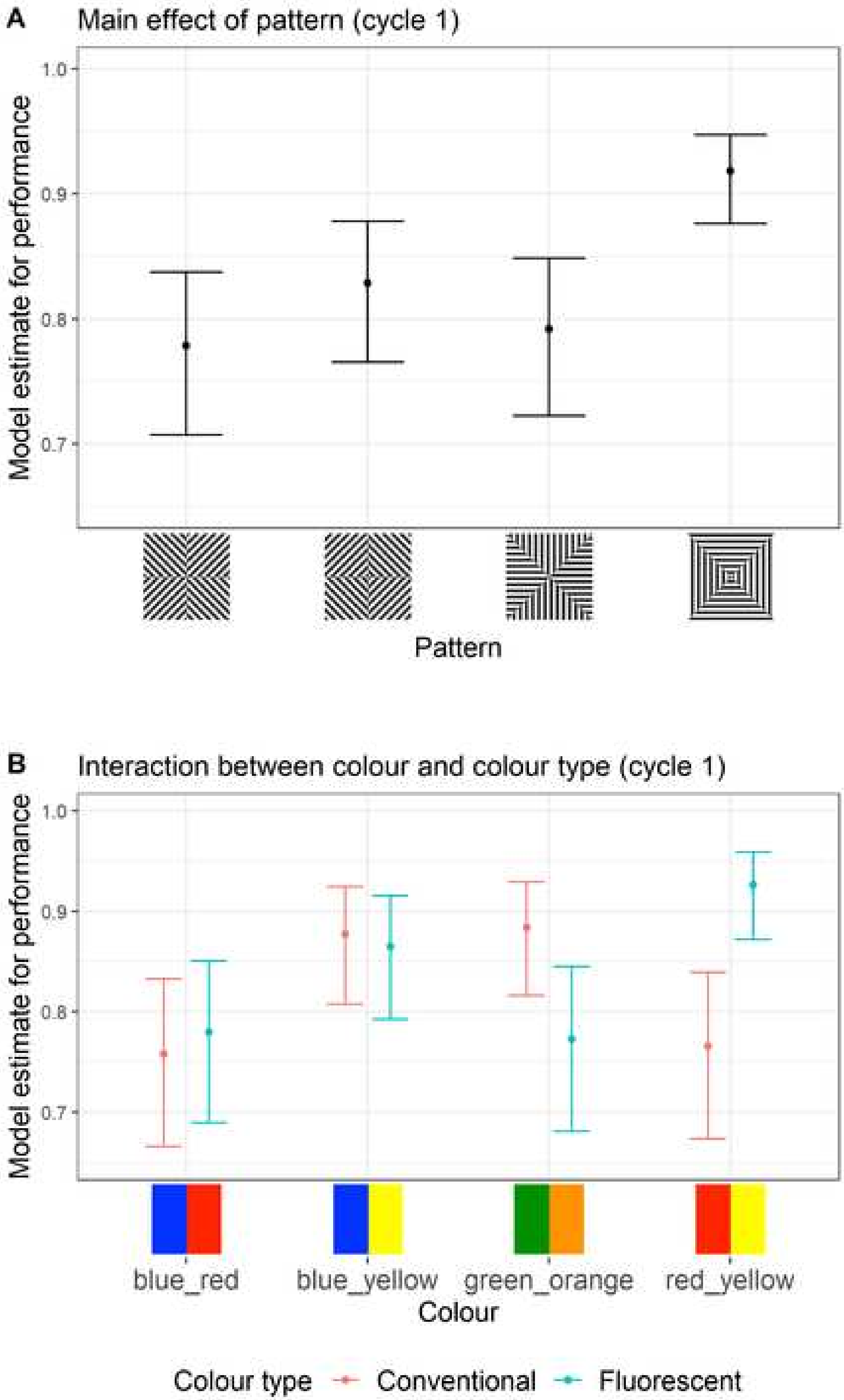

Figure 12

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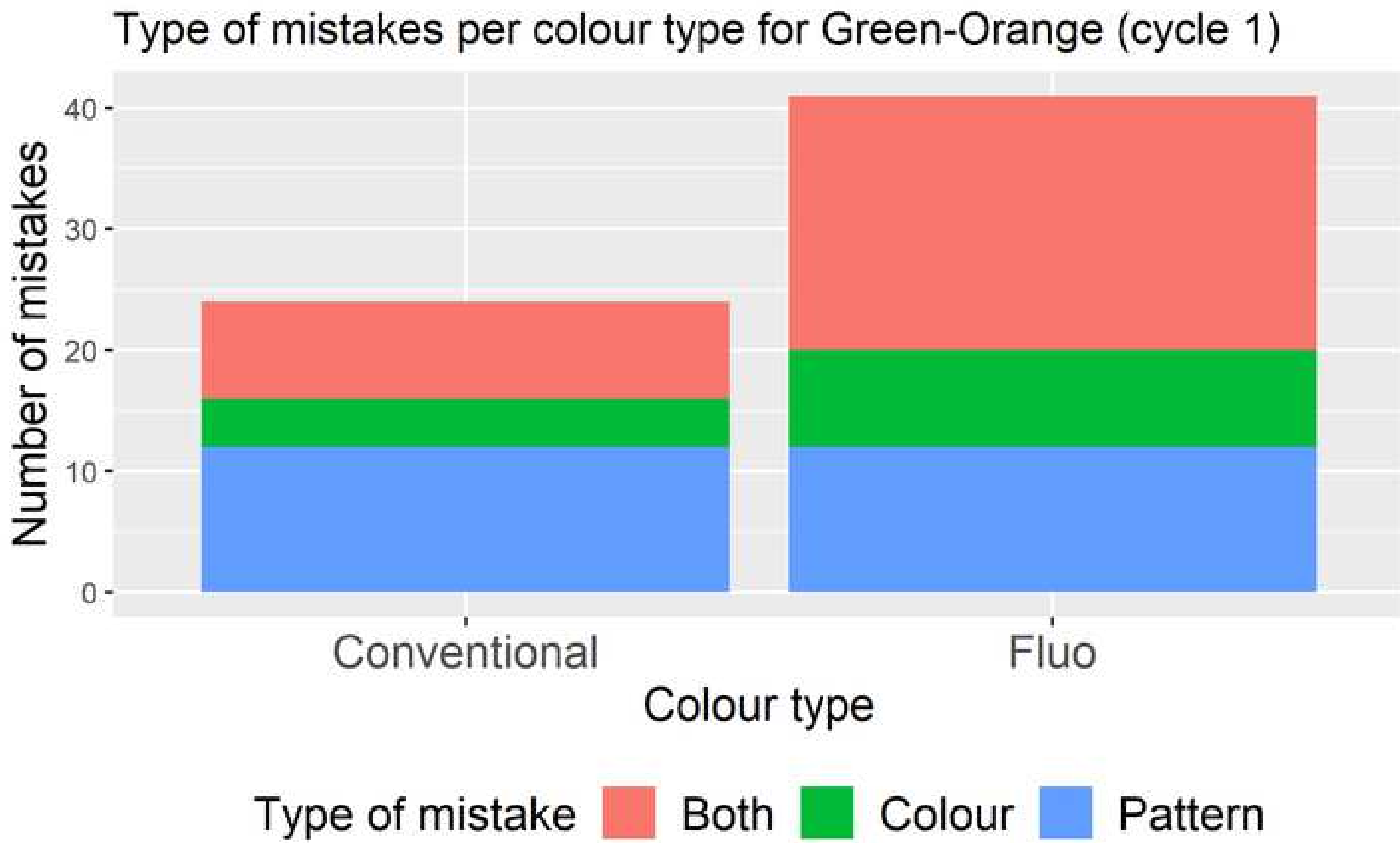

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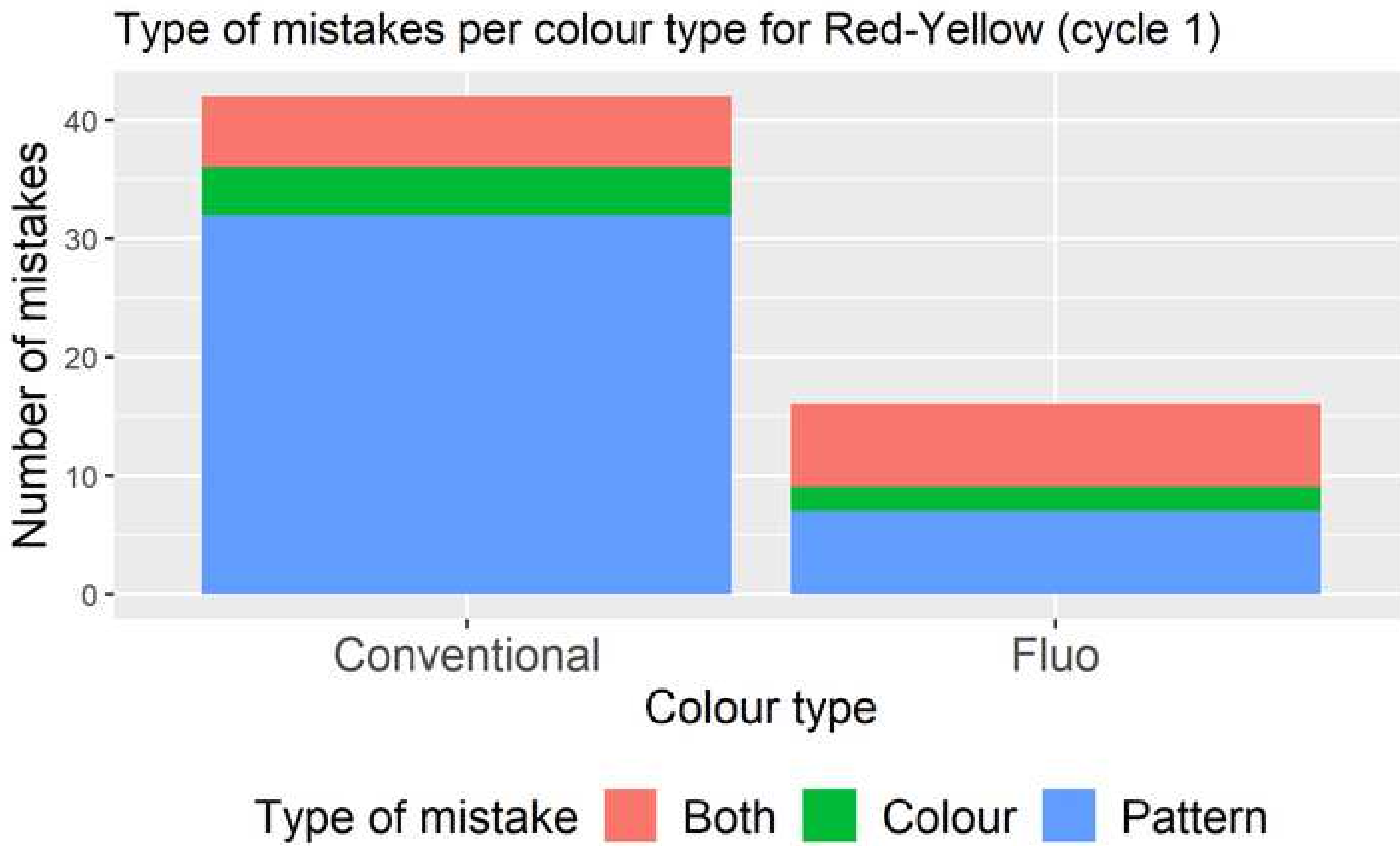

Figure 14

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