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The effect of colour on children's cognitive performance

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Background. The presence of red appears to hamper adults' cognitive performance relative to other colours (see Elliot & Maier, 2014, *Ann. Rev. Psychol.* **65**, 95).

Aims and sample. Here, we investigate whether colour affects cognitive performance in 8- and 9-year-olds.

Method. Children completed a battery of tasks once in the presence of a coloured screen that was one of eight colours and once in the presence of a grey screen. Performance was assessed for each colour relative to the grey baseline, and differences across colours were compared.

Results. We find a significant difference in performance across colours, with significantly worse performance in the presence of red than grey. The effect of colour did not significantly interact with task.

Conclusion. The findings suggest that colour can affect children's cognitive performance and that there is a detrimental effect of red. Findings are related to the adult literature and implications for educational contexts are discussed.

Colour is not just represented in vision, and it can evoke emotional responses (e.g., Vandewalle *et al.*, 2010), aesthetic judgments (e.g., Taylor & Franklin, 2012), and associations to objects and concepts (e.g., Palmer & Schloss, 2010). There is also a growing body of recent evidence that colour can affect performance on cognitive tasks (e.g., see Elliot & Maier, 2014). Whilst many of the early investigations into the effect of colour on cognition and behaviour produced null effects (e.g., Stone & English, 1998), much of this research had poor control over the colours or how colours were viewed, or lacked appropriate rigorous experimental control (see Elliot & Maier, 2007; Whitfield & Whiltshire, 1990). More recent research has attempted to provide a rigorous framework for the investigation of colour performance effects and has revealed a generally consistent pattern of colour effects.

One finding is that the colour red has a negative impact on cognitive performance in adults, at least in some contexts and for some tasks. One of the first studies to show this tested adults' performance on anagram and IQ tests in the presence of red, green, blue, or grey (Elliot, Maier, Moller, Friedman, & Meinhardt, 2007). When the front cover of the IQ test was red, participants scored worse than when the front cover was one of the other colours, and participants also selected easier items to complete. These effects appeared to occur in the absence of awareness since participants could not communicate that the aim of the study was related to colour when quizzed at the end of the testing sessions. The

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effect of red on cognitive performance has also been replicated in several studies (e.g., Shi, Zhang, & Jiang, 2015; Thorstenson, 2015) and effects have been found even if only the word 'red' rather than the colour is viewed (Lichtenfeld, Maier, Elliot, & Pekrun, 2009). It has been argued that red is 'likely to impair any sort of performance that requires more than a modicum of cognitive capacity, mental manipulation or flexible and efficient processing' (Maier, Elliot, & Lichtenfeld, 2008, p. 1537).

One proposition for why red appears to impair cognitive performance is that red constricts attentional focus and therefore hampers performance on tasks which require more than a narrow focus of attention (Maier *et al.*, 2008). There is some evidence that red leads to a 'local bias' in processing and a focus on details rather than the 'bigger picture'. For example, one study has found, across a series of experiments, that red relative to blue enhances performance on detail oriented tasks (Mehta & Zhu, 2009). That study also found that blue enhanced performance relative to red on creative tasks. This raises the possibility that other colours could affect cognitive performance (e.g., that blue enhances creativity). A subsequent study has also found effects of colour on creativity, although that study found that a brief glimpse of green appeared to enhance picture and word creativity relative to white, grey, red, or blue (Lichtenfeld, Elliot, Maier, & Pekrun, 2012).

These effects of colour on performance have typically been explained by the associations that humans have with different colours in different contexts (Meier, D'Agostino, Elliot, Maier, & Wilkowski, 2012). For example, for the negative effect of red on cognitive performance, it has been highlighted that red in certain contexts is associated with danger or warning signals (e.g., Setchell & Jean Wickings, 2005) and that this can evoke a threat response (e.g., Elliot & Aarts, 2011; Hill & Barton, 2005) which might lead to 'avoidance motivation' that then impairs performance on the cognitive task (e.g., Elliot *et al.*, 2007). It has also been found that whereas green is positively associated with success words, red is negatively associated with success words and positively associated with words related to failure (Moller, Elliot, & Maier, 2009). This link between red and failure might also be seen by teachers' use of red ink to indicate errors in schoolwork (Elliot *et al.*, 2007). In fact, one study has even found that essays were marked as having more errors and lower grades when marked in a red pen than a blue pen (Rutchick, Slepian, & Ferris, 2010). It has been argued that the association between red and failure could prime poorer performance on cognitive tasks when conducted in achievement contexts (e.g., Elliot *et al.*, 2007).

Although there are now several examples of the harmful effects of red on cognitive performance, some studies have failed to replicate effects of colour on cognitive performance (e.g., Küller, Mikellides, & Janssens, 2009; Larsson & von Stumm, 2015) or have only found effects for males and not females (e.g., Gnambs, Appel, & Batinic, 2010). Studies where effects have not been replicated may reveal a lack of reliability in the effect of red on cognitive performance. There may also have been nuanced differences in the methods and procedures compared to studies which report effects. Alternatively, the lack of replication may point to the context specificity of the effects. For example, if the effects of red on cognition are highly specific and require the setting of an achievement context in which threat of failure is sensed (Elliot *et al.*, 2007), then studies which fail to find effects of red may not have successfully induced that type of context. In support of the argument that the negative effect of red depends on context, one study has found that the strength of the effect is moderated by the extent of participants' self-control (Bertrams, Baumeister, Englert, & Furley, 2015). Alternatively, the red effect on cognitive performance may not be as pervasive and generalizable as originally assumed. In support of this, one recent study has revealed that whereas red relative to green hampers Chinese students IQ test scores, the reverse effect occurs for Chinese stockbrokers (Zhang & Han, 2014). Although this reverse effect shows that red is not always bad in a cognitive performance context, it was argued that an associative mechanism is still the cause of the effect as in the stock market in China red actually indicates a rise in stock price (success) whereas green indicates a decrease (failure).

In the current investigation, we further explore the effect of colour on cognitive performance and consider whether such effects are present for children in a classroom context. With the exception of one study which assessed the affect of red, grey, and blue on children's grip strength (Elliot & Aarts, 2011), the question of whether colour affects children's performance has been largely neglected. A few studies have found an advantage in children's test performance when tests are printed on white pages compared to pages printed in primary colours but no advantage of white pages compared to desaturated and lighter colours (e.g., Clary, Wandersee, & Elias, 2007; Fordham & Hayes, 2009; Meyer & Bagwell, 2012; Skinner, 2004; Tal, Akers, & Hodge, 2008).

There are a number of reasons why effects of colour on cognitive performance should be further investigated in children. First, this enables a further test of how replicable and generalizable the effect of colour on performance is. Second, as with many psychological effects, investigating the phenomenon developmentally may provide greater understanding of the underlying mechanisms of the effects (e.g., the extent to which effects are learnt). Third, given that theories on the effect of colour and behaviour emphasize that effects are contextual (e.g., Meier *et al.*, 2012), it is necessary to investigate whether effects are present in other contexts such as a classroom and educational context. Fourth, whilst effects of colour on performance have been revealed in scientific investigations conducted under controlled conditions and often in a laboratory context, there is much thirst for these effects to be applied and used in the real world. If effects of colour on cognitive performance were also found in children, this would highlight potential for such effects to be applied to educational settings to enhance and foster learning in children (e.g., Barrett, Zhang, Moffat, & Kobbacy, 2013). Using colour to enhance learning in children is a longer term potential goal that would need scientific testing (e.g., effects may 'wash' out over time), although the first step is to assess whether effects of colour on cognitive performance are found in children at all.

In the current investigation, we adopt a similar approach to adult investigations of colour performance effects. Children complete a battery of cognitive tasks in the presence of one of a number of colours and performance is compared across colours. However, we also make several modifications to the typical method used in adult studies. First, we extend the number of colours tested and compare across 8 colours. Prior research typically compares across only a small number of colours (e.g., two or three) including a grey or white. This means that potential effects of other untested colours (e.g., orange, purple, pink) are not documented and it could also mean that effects related to the similarity of hues (e.g., orange is similar to red so does orange hurt cognitive performance too but to a lesser extent?) are missed.

Second, we choose good examples of seven basic colour categories (red, yellow, green, blue, orange, purple, pink) as well as light blue, and therefore rather than varying hue at constant chroma and lightness, colours vary along all three psychological dimensions. It has been claimed that having colours that vary on all three dimensions is a limitation of the early work on the effects of colour on performance (e.g., Elliot *et al.*, 2007). This may well be the case if only a few colours are tested, but if there are a greater number of colours tested and their colorimetric properties are measured and defined, then such stimulus variation can be used to investigate whether there are important effects of the psychological dimensions of colour (e.g., lightness, saturation, and the red–green and blue–yellow subsystems of colour vision) on colour performance rather than only highlighting effects for hue (e.g., effects can be correlated with lightness or saturation across colours). In the real world, colours vary on all three dimensions and colour is perceived integrally (e.g., Burns & Shepp, 1988). Therefore, selecting out only hue is an artificial representation of how we experience and see colour. Importantly, our colour associations also map onto three-dimensional colour space and are related not only to hue but also to lightness and saturation (e.g., red might indicate failure but the darkness of a colour might also do so). If effects of colour on performance are due to associations, then to have the greatest chance of revealing these effects, the colours which drive the strongest associations should be used. We reason that as many associations are lexically grounded (e.g., we say 'seeing red' as an indication of anger; Fetterman, Robinson, Gordon, & Elliot, 2010), the colours which are likely to provide the strongest associations are likely to be the best examples of given colour terms (which capture a broad range of colour space along all three dimensions). This provides further motivation for using good examples of the basic colour categories here.

Third, prior studies have varied in how they expose participants to colour during the experiment. For example, colour has been displayed in the form of a front cover, the experimenter's T-shirt, and a semantic word. The duration of exposure to colour has also varied. Here, we display colour in the form of a coloured screen which sits in front of children whilst they complete their test booklet. The colour is visible whilst children complete test items, but the duration of exposure is strictly controlled (lack of control over duration of exposure has been cited as a limitation of early work, Elliot *et al.*, 2007). We considered more subtle use of colour (e.g., having colour only briefly viewed at the start of the test). However, we were concerned that children's easy distraction might mean that some children do not notice or process a briefly presented colour. In addition, given that we do not know whether effects of colour on children's performance are found at all, we felt that maximal exposure to colour would be a good first step to take – more subtle exposure to colour could then be investigated in further research if effects are found.

Fourth, each child completed two halves of a booklet which had the same tasks but different questions or examples. One half of the booklet was conducted in the presence of coloured screen and the other half in the presence of a grey screen. The half of the booklet that was conducted in the presence of a grey screen or coloured screen was counterbalanced across participants for each colour. This enabled us to use performance in the grey condition as a baseline measure (see also Larsson & von Stumm, 2015, who also have a non-colour baseline measure in their study). Each child's scores under the grey condition were subtracted from their colour condition scores enabling us to control for individual differences. Individual differences in performance may be especially great for school children (where children of all abilities are in a class) compared to the university students tested previously who will have passed a certain educational attainment level. Testing children in the presence of a grey and a coloured screen may mean that children guess the goal of the study and that any effects found are not 'unconscious', but determining whether effects of any nature are found in children is the first step and the 'unconscious' nature of any effects can be probed in further investigations.

Finally, we include a range of cognitive tasks in our test battery. These have been selected to be closely related to the types of tasks usually conducted in a classroom context. We assess reading comprehension and numeracy using samples of government test papers, and also assess originality and detail on a collage making task. We also include our own version of an 'embedded figures' style task where children have to find a shape in a larger picture. The embedded figures task was originally designed by Witkin to measure 'field independence' – a cognitive style which relates to the ability to separate items from surrounding context (e.g., Witkin, Oltman, Raskin, & Karp, 1971). However, it has since been linked to a range of other cognitive and perceptual skills as well as forms of perceptual bias (Van der Hallen, Chamberlain, de-Wit, & Wagemans, 2015). For example, enhanced performance of those with autism on the task has been attributed to 'weak central coherence' – the reduced ability to perceive the integrated global 'whole' and superiority in seeing the local elements (e.g., Shah & Frith, 1983; but see also White & Saldaña, 2011). We use our version of the task here as a broad measure of cognitive and perceptual visuospatial skills without making strong claims that the task is isolating more specific perceptual or cognitive constructs. We also include a picture maze task in our test battery where children are required to draw a line from the start to the end of a maze. This task is included as a measure of fine motor skills but is also likely to tap attention to detail. Emotional state (sad–happy; calm–excited) is assessed using a self-assessment manikin, and children are also asked to rate their colour preference for their coloured screen to see whether performance is enhanced in the presence of preferred colours. We also add gender as a factor to our analyses as gender differences have been documented for colour preference and colour associations (e.g., Taylor & Franklin, 2012) and one prior study has found gender differences for the effect of colour on performance in adults (Gnambs *et al.*, 2010). If effects of colour on performance in children are the same as those in adults, then certain predictions about some of the tasks can be made: (1) performance on the cognitive tasks should be reduced in the presence of red relative to other colours (e.g., Elliot *et al.*, 2007); and (2) performance on the creative collage task should be enhanced for blue or green relative to other colours (e.g., Lichtenfeld *et al.*, 2012; Mehta & Zhu, 2009).

Method

Participants

Three hundred and fifty-nine male and female children from 11 schools in the East Sussex and Kent regions of the United Kingdom took part in the project. Schools were a mixture of state and private schools and varied in size and socio-economic background. One hundred and fifty-six 8-year-olds (88 female) and 149 9-year-olds (74 female) took part (mean age = 8.47 years, standard deviation = 0.5).[1] Parental consent for children's participation in the study was given for all children, and children also assented to taking part. Children were told that their participation was voluntary and that they could stop their participation at any point. The project was approved by the University's Ethics Committee.

Stimuli

Stimuli were 6 colours judged to be good examples of the basic colour categories red, green, yellow, blue, purple, and orange, and additionally a light blue and light red (to enable the dimension of lightness to be explored) along with a mid-lightness grey. Table 1 gives the colour co-ordinates when measured by a Photo Research PR655 spectroradiometer under D65 illuminant (simulated natural daylight).

[1] *A smaller sample of 10-year-olds (*$n = 54$*) were tested but as it was revealed that the majority of the children in this age group were at ceiling, data collection for this age group was halted, and the small number of 10-year-olds tested were not included in the final analysis.*

Colours were presented in the form of painted A3 boards (of roughly 0.3 mm thickness, painted with matte paint). The boards had two white side flaps (each ½ of an A3 board) attached by tape on the back surface of the board. The side flaps enabled the board to be stood upright and created a 'booth' for the children to work in.

Design and Procedure

Children completed a test booklet in the presence of a coloured screen and a grey screen. The coloured screen was one of 8 colours (see stimulus section). The order of the coloured and grey screen was counterbalanced for each colour condition such that 50% of the participants did the first half of the booklet in the presence of the coloured screen and the second half in the presence of the grey screen (and vice versa for the other 50%). The order of coloured or grey screen was kept constant within a testing session, and within each testing session, the coloured screens were randomly distributed. Two researchers gave the screens to children whilst the children sat at their tables. The pile of screens to be distributed was randomly shuffled and the researchers distributed the screens in that order, working from the front to the back of the classroom so that there was no bias in allocation. Once given the screen, children set the screen up in front of them by pulling out the side flaps. Once all screens were in place, children were given 18 min to complete the first half of the booklet, after which the children were asked to put their pens down and the screens were collected back in by the two researchers. The second set of screens was then distributed in the same manner as the first and children were asked to sit quietly whilst this was done. Children were then given 18 min to complete the second half of the booklet. Children were tested in their classrooms at their tables and in groups of up to 30 in the normal lighting conditions for their classrooms. Children were not told the hypotheses of the study prior to taking part.

Test booklets were made up of seven tasks, and there were two versions of each task which appeared in the first and second half of the booklet. The seven tasks were intended to measure a range of cognitive skills as well as fine motor skills and to gauge children's emotional state and preference for colours. The tasks are outlined below.

Table 1. Chromaticity and luminance co-ordinates for the stimuli (CIE, x, y, Y, 2 degree observer) as measured under D65 illumination (simulated natural daylight, standard white measured under illumination: x = 0.31, y = 0.33, Y = 257 cd/m^2)

Colour	x	y	Y	Hue (degrees)	Chroma
Red	0.593	0.338	33	10.95	214.98
Orange	0.538	0.417	92.4	28.44	201.37
Yellow	0.449	0.517	174	73.24	163.26
Green	0.274	0.53	81.1	136.10	130.76
Blue	0.189	0.204	26.7	249.89	111.28
Purple	0.249	0.199	29.8	276.44	106.03
Light Red	0.355	0.352	172	19.16	53.12
Light Blue	0.283	0.32	142	239.13	36.51
Grey	0.312	0.346	65.6	10.95	

Hue and Chroma (CIE, 1976) use the grey as the white point for conversions as the grey board was the baseline for the experiment.

Emotional state

Children completed a self-assessment manikin in the presence of the coloured screen and in the presence of the grey screen. This involved rating their state from sad–happy and calm–excited on a 5-point scale.

Colour preference

Children were asked to rate how much they liked the colour of their board on a five-point scale ranging from 'don't like a lot' to 'do like a lot' (see Figure 1 below).

Numeracy

Children's numerical ability was assessed using samples of age-appropriate government tests of numeracy that are routinely administered in schools. There were 10 questions involving addition and other numerical calculations.

Reading

Children's reading comprehension was assessed using samples of age-appropriate government tests of reading that are routinely administered in schools. Children were first given a sample of text to read and then there were 10 questions assessing their comprehension of the text.

Embedded figures

Children were given novel examples of an 'embedded figures' style test where children were shown a target shape and asked to find it within a picture. Once they found the shape, they were required to shade it in. The task involves discriminating items in the picture and ignoring the surrounding context of the picture (e.g., that the picture is of a dog).

Fine motor skills

To measure fine motor skills, we used a pictorial maze task where children had to get from the start of the maze to the end of the maze under timed conditions without crossing the lines. The number of times the lines were crossed was analysed.

Collage Originality and Detail

Children were given a set of 10 cut-out paper shapes and were asked to make an interesting picture using 5 of the shapes, to annotate the picture with their pencil and to give it a title. One experimenter rated the pictures on how original they were (e.g., to what extent did others use the shapes in the same way) and how much detail was in the picture (on a 0- to 5-point scale). Scoring was guided by the approach in study 4 of Mehta and Zhu (2009) and by the scoring on Jellen and Urban's (1986) test for creative thinking and drawing production. The coder was blind to the colour condition when rating the pictures.

At the end of the booklet, children were thanked for taking part and were given a fun age-appropriate exercise booklet on colours as a thank you for taking part.

Results

Emotional state and preference were scored 1–5 based on children's responses. Percentage accuracy scores were calculated for reading, numeracy, embedded figures, and collage originality and detail for first and second halves of the booklet. The maze task measuring fine motor skills could not be converted to a percentage accuracy score since the number of errors on the task was unlimited, and therefore the number of errors was simply analysed.

Children's performance in the context of the grey screen was used as a baseline for all scores. Each child's score/rating on the tasks when completed in the presence of the grey screen was taken away from their score when completing tasks in the presence of the coloured screen: (colour performance – grey performance). This was done to control for individual differences in ability that could lead to differences in performance across conditions. Therefore, the resulting scores represent how much better (positive scores) or worse (negative scores) each child does under the colour condition relative to the grey condition. The colour-grey scores on each task were then analysed to compare the scores across colours using ANOVA (or Kruskal–Wallis for ordinal data).[2] Where there is a significant main effect of colour in the ANOVA, one-sample t-tests are then used to compare each colour to 0 (0 represents equal scores for grey and colour conditions) to identify colours where performance is significantly greater or less than grey.

Colour Preference

Figure 1 provides the mean preference rating (out of 5) for children who had screens of various colours. Two children did not rate their preference and were therefore excluded

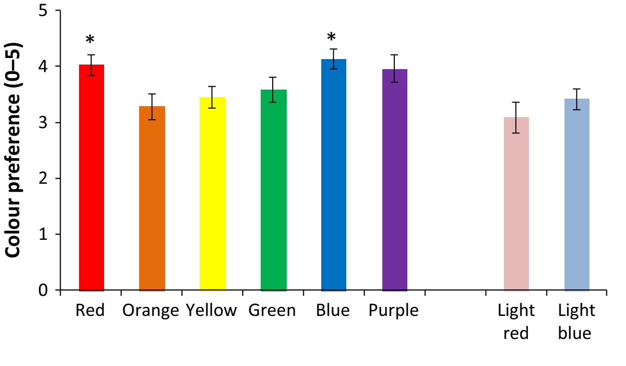

Figure 1. Mean colour preference ratings for each of the colours (±1 *SE*). Significant differences to the average preference rating are marked with an asterisk.

[2] *Note that there are alternative ways to analysing the data. For example, rather than analysing the colour-grey performance scores as we do, screen type (colour/grey) could be added as an extra factor into the ANOVA, or average performance in the presence of a grey screen could be added as a covariate. All of these approaches produce identical findings and we present the analysis of colour-grey performance scores as this is the analysis which is most accessible.*

from the analysis. A two-way ANOVA with Colour (red, orange, yellow, green, blue, purple, light red, light blue) and Gender (male, female) as factors revealed a significant difference in preference across colours, $F(7, 280) = 3.13$, $p = .003$. There was no main effect of Gender on preference scores, $F(1, 280) = 0.29$, $p = .59$, but there was an interaction of Colour and Gender, $F(7, 280) = 2.33$, $p = .025$. One-sample *t*-tests with the mean preference rating (3.6) as a test value revealed significantly stronger preferences for red and blue than the average preference, red: $t(39) = 2.26$, $p = .029$, $d = .36$, small effect; blue: $t(37) = 3.06$, $p = .004$, $d = .50$, medium effect. Independent *t*-tests on preference ratings of each colour with Gender as a factor revealed that males preferred red (mean = 4.52, $SD = 0.81$) more than females (mean = 3.47, $SD = 1.31$), $t(30) = 3.0$, $p = .005$, but all other gender differences were not significant (largest $t = 1.69$, smallest $p = .103$).

A regression analysis which entered children's preference rating for the colour of their screen as a predictor of total performance across the cognitive tasks (reading, comprehension, embedded figures, collage creativity, and detail) failed to find any evidence of an effect ($R^2 = .002$, $p = .40$).

Emotional response

Figure 2 gives the scores for how happy–sad and excited–calm the children rated themselves when in the presence of the coloured screen relative to the grey screen (colour rating – grey rating). Kruskal–Wallis tests (ordinal data) were conducted on these scores with Colour as a factor, and this revealed no significant differences across colours in happiness ($p = .33$), or in excitement ($p = .66$). Mann–Whitney *U*-tests were conducted on the scores for each colour with Gender as a factor, revealing only one gender difference which was for children's rating of their happiness in the presence of the blue screen relative to the grey screen (mean rating females = 13.75, $SD = 14.08$, mean rating males = -7.27, $SD = 18.04$), $Z = -3.69$, $p = .001$ (all others largest $Z = -1.67$, smallest $p = .095$).

Cognitive performance

Figure 3 gives the performance across different colours for reading, numeracy, embedded figures, and collage creativity and detail and for the overall performance score (averaged

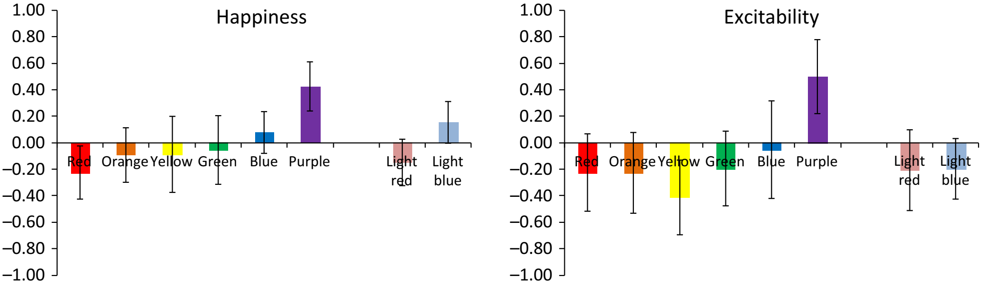

Figure 2. Children's mean self-assessment scores on happy–sad and excited–calm scales when in the presence of a coloured screen relative to a grey screen (colour rating – grey rating) for each of the colours (±1 *SE*).

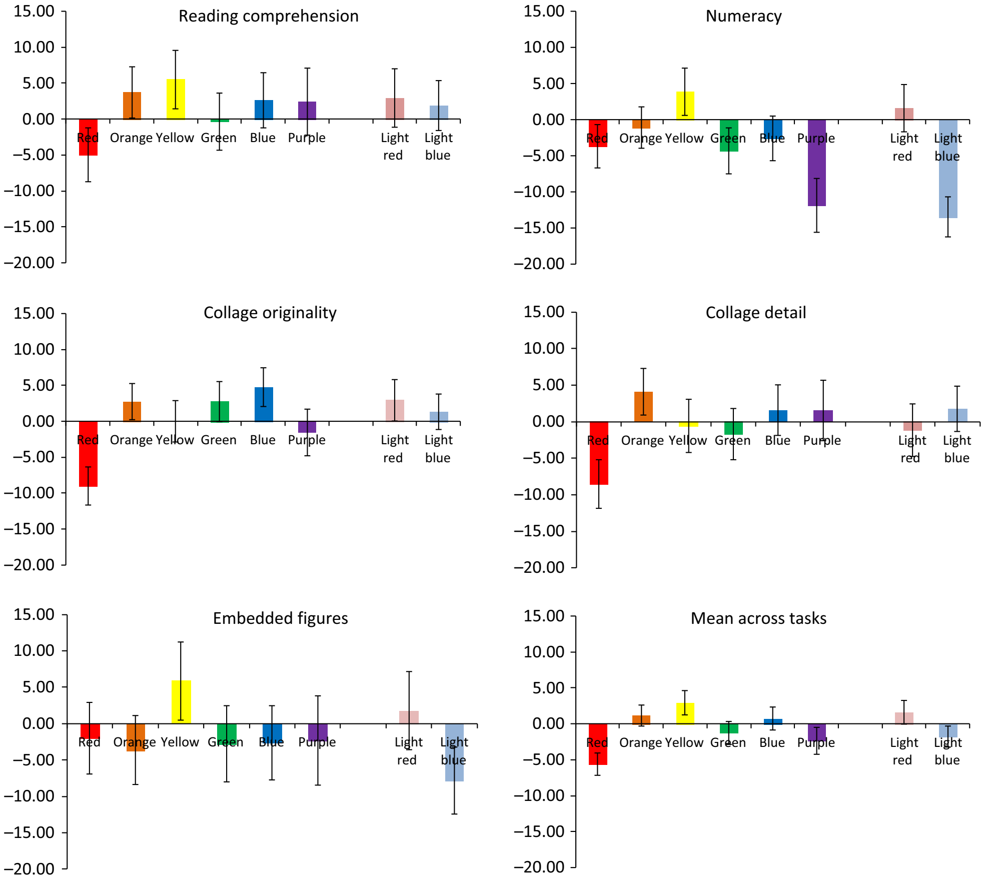

Figure 3. Children's performance on cognitive tasks when completed in the presence of a colour relative to grey (colour score – grey score) for each task and the average performance across tasks (±1 *SE*).

across tests) when collapsed across tasks (the colour-grey score averaged across). An ANOVA was conducted on the data with Colour, Task (reading, numeracy, embedded figures, and collage originality and detail), Gender, and Order (colour first, grey first) as factors. There was a significant main effect of Colour, $F(7, 266) = 2.62$, $p = .012$, that did not interact with Task, $F(4, 1064) = .81$, $p = .74$, Gender, $F(7, 266) = .53$, $p = .81$, or Order, $F(7, 266) = .41$, $p = .90$. The main effect of Colour was further explored by conducting one-sample *t*-tests for each colour against a value of 0 for the mean performance score averaged across tasks. These found a significant effect for red, where red hampered performance relative to grey by around 6%, $t(39) = 3.68$, $p = .001$, $d = .58$, medium effect. No other significant effects of colour relative to grey were found, all $p > .05$.

Fine motor skills

Figure 4 gives the number of errors children make on the fine motor skill maze task for colour relative to grey. A three-way ANOVA with Colour, Gender, and Order as factors did not find a significant difference in errors across colours, $F(7, 266) = .52$, $p = .82$, or a

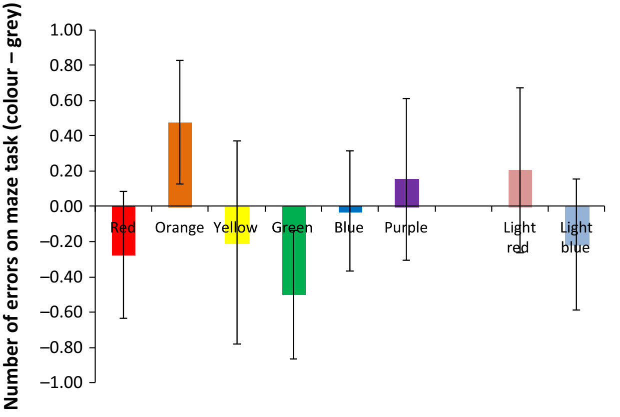

Figure 4. The average number of errors on the maze task in the presence a colour relative to grey (colour – grey) for each colour (± 1 *SE*).

significant interaction of Colour with Gender or Order (largest $F = 1.11$, smallest $p = .36$). One-sample *t*-tests testing each colour against a value of 0 found no significant effects of colour relative to grey, all $p > .05$.

Discussion

Main findings

The current investigation finds that the colour of a screen viewed during test completion can affect children's performance on a range of cognitive tasks. The overall pattern of effect was that red significantly hurt performance on the cognitive tasks by around 6% relative to a grey baseline. No other colours significantly enhanced or hurt performance on overall test performance relative to grey. This pattern did not significantly interact with type of test even though differences in the pattern could be seen for some tests (e.g., for numeracy purple and light blue also appeared to hurt performance relative to grey). However, given the lack of significant interaction between Colour and Task, we are unable to state that the effect of colour reliably varies across task, and the conclusion based on the statistical analysis is that red broadly hurts cognitive performance. The effect of colour on task performance was not significantly different for males and females. However, females were found to have higher happiness ratings than males when completing the tasks in the presence of blue relative to grey.

Children's pattern of colour preference was found to be highly similar to that of UK and US adults (e.g., Palmer & Schloss, 2010; Taylor & Franklin, 2012): The children had a peak of preference at blue and a minimum around yellow–orange. The only gender difference in preference was that males preferred red significantly more than females. A regression analysis failed to find any evidence that children's cognitive performance was significantly better if children liked the colour that they had been allocated.

Relating the findings to the literature

The findings of the current study show that prior claims of the effect of red on adults' cognitive performance (e.g., Elliot & Maier, 2014) can, in certain circumstances, also extend to children. However, red was found to be broadly harmful to performance across different tasks. Whereas the adult literature has pointed to blue and green enhancing creativity, we find no evidence of that effect in children: In children, it appears that the presence of red when children make collages leads to poorer ratings of originality in those collages when compared to grey and that no effects are found for other colours. This difference between the adult and child effects may relate to the context in which the tasks are done. Even though the collage task taps creative skills, in the context of a test booklet administered in school, the children may evaluate this as an 'attainment success/failure' type task.

What causes the effect of red on children's performance?

The underlying mechanism of the effect of colour on children's cognitive performance may well be similar to that proposed for adult effects. Children may also associate red with failure or danger and perceive threat in the context of that colour and modify how they approach a task in the presence of red as a result. Even children as young as 3 years are able to associate colours with emotion (Zentner, 2001) and so it is possible that colour associations are at the heart of the effect of colour on cognitive performance that we find at 8 and 9 years. The effect of red on performance for children appears not to be related to lightness or chroma since a relationship of test performance and the lightness or chroma of colours cannot be seen in the data (a good example of red is of a similar lightness to blue and purple and a similar chroma to orange, yet only effects for red were found). The effect of red also appears to not be generalizable to a particular hue since effects were not found for light red (pink) which was of a similar hue as the red but lighter and less saturated. Therefore, we propose here that the effects of colour on cognitive performance are categorical – they depend not on the dimensions of colour but rather on how a particular colour is named and the associations related to that colour name.

Notes of caution

We show here that red appears to hamper performance on cognitive tasks relative to grey for a sample of 8- and 9-year-olds. Whilst we are excited by this effect, we are also cautious in the inferences that can be made from it. First, we make no claims about whether this effect occurs outside of children's consciousness as has been claimed in the adult literature, which is a question for further investigation. Second, we should also be careful not to overgeneralize the 'red effect' to children from all cultures. Zhang and Han (2014) study of the effect of colour in Chinese stockbrokers (Zhang & Han, 2014) suggests that colour associations modulate the effect of colour on performance and we know from other research that colour associations vary across cultures (e.g.,Taylor, Clifford, & Franklin, 2013). Third, using these findings in an applied context should be done with caution until further research has established whether such effects are influential enough to be active in the 'real world'. One issue is whether effects would 'wash out' over time, for example, whether children would habituate to the effects of colour if the colour was present continuously in their classroom. Further scientific research is needed to investigate these issues.

Conclusions

Here, we demonstrate for the first time in a study with appropriate design and controls, a significant effect of colour on children's cognitive performance on a range of education-related tasks. The findings suggest that the negative effects of red on cognitive performance that have previously been documented for adults are also active in children. Overall, the findings suggest colour is not just a visual stimulus for children but that it evokes aesthetic responses and that colour can have subtle influence over performance on education-related tasks.

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