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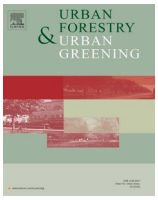

Original article

Flowers – Sunshine for the soul! How does floral colour influence preference, feelings of relaxation and positive up-lift?

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ABSTRACT

The natural environment is increasingly valued for its positive effect in retaining/restoring good mental health. Landscape architects are now challenged to embed therapeutic aspects within certain landscape designs, but what does this mean in practice? Flower colour has been one area that has attracted attention as potentially improving the restorative aspects of a designed landscape. In this research, 670 UK residents were surveyed to examine their preferences and emotional responses to flower colour using computer-generated images of 'daisy-like' flowers in 8 separate colours. Results showed that white, blue and orange were the most preferred flower colours. The data suggested, however, two separate phenomena were determining the psychological benefits associated with flower colour. The first is that there are some generic responses associated with key floral colours – flowers in blue play an effective role in relaxation/stress reduction; and warm colours - orange, yellow and red evoke uplifted emotions and deliver better positive affect. Interestingly, white was a colour that could both relax and provide uplifted emotions. The second phenomenon though, suggests that additionally and independently, an individual preference for a particular colour can also elicit positive psychological benefits, irrespective of what that particular colour is. In effect, favoured colours have a separate restorative effect that acts at a personal level. This finding has significance for landscape architects in that certain flower colours can be used to promote 'generic' therapeutic responses in appropriate locations, but that components of any designed landscape still need to take some account of personal responses and preferences.

1. Introduction

> "Flowers always make people better, happier and more helpful; they are sunshine, food and medicine for the soul." Luther Burbank – Plant Breeder.

Poor mental health affects 19% of adults, 46% of teenagers, and 13% of children worldwide, each year (Swetaa et al., 2019). It is the second-largest cause of disease and health disorders in England, UK (The Mental Health First Aid, MHFA). Despite this, 70–75% of people with diagnosable mental illness receive no formal therapeutic interventions (Alonso et al., 2018). An increased emphasis on prevention rather than cure (Scott et al., 2019) and holistic therapies (Greenleaf et al., 2014) has highlighted the need for more opportunities for mental restoration to be gained through 'everyday activities' and lifestyle changes, particularly those that reduce stress or loneliness (Rentala et al., 2015). Green (or eco-) therapy, an umbrella term for nature-based approaches to healing, is one mode of action to reduce the occurrence of mental illness in the first place (Burls, 2007) and provides restorative effects to those suffering from more mild forms of it (William et al., 2009).

Empirical studies have demonstrated that contact with natural environments (van den Berg et al., 2003; Bowler et al., 2010; Pasanen et al., 2018) and semi-natural environments (Groenewegen et al., 2006; Kondo et al., 2018; Cameron et al., 2020; Chalmin-Pui, et al., 2021a; 2021b) offer effective ways of obtaining better mental health. The causes of mental illness are complex and varied, and the mechanisms for better health or restoration may be similarly complex. A number of underlying theories exist in relation to benefits associated with the natural world with respect to mental health. Commonly cited ones include the attention restoration theory (Kaplan and Kaplan, 1989), stress reduction theory (Ulrich, 1983; Ulrich et al., 1991) and the positive affect theory (Bratman et al., 2015; Richardson et al., 2016; Cameron et al., 2020). Although there are overlaps among the theories, effectively the first two deal with alleviation of physiological stress

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through noticing relaxing or distracting elements within the natural world, while the third theory suggests positive mental health is maintained by experiencing exciting or positive things in nature; aspects that make one happy. As all theories outlined above have an element of protection against (salutogenesis), and restoration from, poor mental health, they are referred to within this paper for their capacity to simply promote good or positive psychological health.

A number of the theories above imply a 'dose effect'. The more incidents of emotional uplift (i.e. 'happy events') an individual encounters the greater the resilience against poor mental health (Teismann et al., 2019; Barnes et al., 2019; Keenan et al., 2021). Similarly, environments that promote opportunities for frequent relaxation can reduce physiological stress (Berto, 2014; Chalmin-Pui et al., 2021b); prolonged stress itself, being considered a precursor to both psychological (e.g. Stogner et al., 2020) and physiological (e.g. Miller et al., 2011) health complaints. Experiencing frequent, regular periods of emotional uplift or periods of relaxation provide resilience against certain forms of poor mental health. Thus, in this research, short-term emotional responses are recorded (self-reported feelings of uplift and relaxation) and used as proxies (indicators) of resilience against more significant and long-term mental health problems. This does not imply of course, that mental health is solely determined by an accumulation of short-term emotions. Nevertheless, such proxies are useful to help determine what aspects of landscape may or may not be salutogenic.

Despite numerous studies on green therapy, there is still a deficiency in understanding how elements of the landscape act or combine to influence human health (Gatersleben and Andrews, 2013). For example, more information is required on how relatively small-scale 'quality aspects' of green space (e.g. noticing an individual bird or a wildflower) can impact psychological health (Collins et al., 2020). Research has shown that in non-natural settings (indoor rooms), small-scale interventions such as a picture or photograph of a natural object or scene, can affect the mood of those that view them (Jo et al., 2019). A phenomenon that has been exploited by hospitals who, for example, may wish to calm their patients whilst waiting or recovering from medical interventions (Beukeboom et al., 2012). These studies imply small scale interventions can influence emotions, but also by doing so, influence medical outcomes.

These factors are important, because increasingly landscape architects are being asked to design 'therapeutic landscapes', as preventative measure against negative emotions or excessive stress, but also as restorative environments for those that are suffering poor mental health or trauma. Yet there is limited information on what specifically should be included in such therapeutic landscapes, and where recommendations are provided these are often based on anecdotal evidence rather than empirical data. Features quoted as being therapeutic within designed landscapes include water, (non-threatening) fauna, 'natural' sounds and colourful flowers. Yet, little further detail is provided – what types and colour of flowers for example? Indeed, does something like flower colour matter at all? Presumably for a landscape as a whole to be therapeutic it, then it needs to be composed of smaller features such as plantings that are themselves beneficial from an emotional perspective. For many ecosystem services, the level of the benefit is defined by quite subtle, small-scale factors (Cameron and Blanusa, 2016); but is this true of emotional responses to natural features too, in essence does the detail matter (Jo et al., 2019)?

Thus, this research focussed on how the 'fine-grained' detailed aspects of landscape might impact on emotional responses and how such responses act as proxy for wider health issues. Previous research from this group (Chalmin-Pui et al., 2021a) indicated that small scale interventions (such as a container of flowering bulbs and annual plants placed outside the front door of a house) had a significant effect on stress levels and cortisol profiles in the household owners; many of which noted flower colour as an important element. Therefore, this research aimed to address one aspect of landscape detail – namely flower colour; and how people respond to this in terms of preference, capacity to relax or feel positive affect ('uplift'). Not only is flower colour a good example of the type of detail that occurs within a designed landscape, but its study is further justified as:

1. Colour is a primary factor people notice when entering a landscape, and is a major determinant when selecting flowering plants or cut flowers (Hansen and Alvarez, 2010).
2. Emotional responses to colour has been studied in other contexts (O'Connor, 2011; Gul et al., 2015; Jonauskaite et al., 2020) and these provide a comparison for this study. Such studies suggest psychological responses varying with colour; red is used to excite, activate and arouse, blue to calm and relax, green to offer equilibrium, and yellow to uplift (Aktekin & Şimaşek, 2012; Azeemi et al., 2019). However, colour therapies are typically conducted in artificial not natural environments (Aktekin and Şimaşek, 2012; Vaquero-Blasco et al., 2020).
3. Existing research recognises the restorative role played by flowers per se (i.e. without specifying the effect of individuals colours). Haviland-Jones et al. (2005) established that flowers, can positively contribute to psychological well-being. Hoyle et al. (2017) noted that the public view brightly coloured flowers as extremely attractive and stimulating.
4. Several studies have acknowledged the restorative function of plant or flower colour. Neale et al. (2021) showed that warm flower colours altered heart rate variability and linked this to a restorative influence. Elsadek and Fujii (2014) suggested that entirely green plants promote a more comfortable environment compared to green-red and green-white variegated plants. Kexiu et al. (2021) indicated a cultural context; green and green-white foliage plants enhanced relaxation and calmness in Japanese residents, while light green and green-yellow were the hues that were preferred for inducing calm in Egyptian participants. Most studies focus on foliage colour, with early studies on plant preferences/restorative effects intentionally avoiding colours other than green to remove distractions (Kaplan and Kaplan, 1989). Nevertheless, both positive affect and stress restoration may be influenced by floral colour, independent from foliage hue, thus warranting further study here.
5. Many previous studies on flower colour are: based on anecdotal observations rather than controlled experiments, had only limited participants ($\leq$ 30) or sample populations (e.g. just students), or evaluated only a limited range of colours (Li et al., 2012; Jang et al., 2014). Thus, this research aimed to both extend the choice of flower colour and increase/widen the participant base.

Nevertheless, previous studies on flower colour per se provide some insight into psychological responses. Positive emotions and comments have been linked to orange, red, yellow, red-purple and pink flowers (Wilson, 2011; Jang et al., 2014; Pavlova, 2015; Paddle & Gilliland, 2016; Hoyle et al., 2017), whereas other colours (purple, white, blue, white and blue-purple) have been associated with a relaxation effect (Wilson, 2011; Li et al., 2012; Jang et al., 2014; Pavlova, 2015; Hoyle et al., 2017). This research aimed to verify if these findings are generic, by increasing the number of participants and controlling for contextual factors (variable locations, plant species, conflicts with foliage influence). Even if a single location and plant species is chosen, temporal factors such as weather at the time of viewing, plant development over time (including some flowers fading in colour), or variations in background noise, may mean participants have slightly different experiences of the floral display. Thus, virtual processes (electronic questionnaire with images) were employed rather than using real plants, whilst recognising this approach also has limitations (Sevenant and Antrop, 2011; Voit et al., 2019). Questionnaires using photographs have been used before to elicit responses to flower colour (Li et al., 2012; Hůla and Flegr, 2016; Neale et al., 2021), and whilst this approach does not immerse the participant in the landscape in the way that an in vivo experiment would, it can still be used to determine preferences as well as emotional

and physiological responses (Jo et al., 2019). Photographs can also indicate or imply 'mass plantings', more akin to an in vivo landscape than perhaps individual flowers or pots of flowers displayed in a laboratory can (Jang et al., 2014; Xie et al., 2021). A photo-based questionnaire has the added advantage of allowing for a greater number of participants over a given time, and thus aid statistical robustness.

Preference for a given flower colour (as a defined parameter separate to uplift or relaxation) was included in this study, to see if preference aligned with feeling of emotional uplift or relaxation. Previous research suggests that environmental preference and restoration may be closely related e.g. on landscape type (Herzog et al., 2003; van den Berg et al., 2003) and the number of biotic features (trees, flowers, animals) present (Wang et al., 2019). Restorative effects due to animals may be taxon specific (e.g. many people prefer birds to insects, for example, and thus find the former more therapeutic to watch) (McGinlay et al., 2017). Preference may be an important component of floral studies. Florist shop customers preferred red, lavender and pink flowers over blue, white or yellow flowers (Behe et al., 1999; Yue and Behe, 2010). In roadside plantings, Todorova et al. (2004) found equal preference for a diverse range of flower colours. In contrast, Hůla and Flegr (2016) found blue was the most preferred flower colour, followed by pink and purple with yellow being least popular. Comparisons were made across different flower genotypes however, and potentially flower form and cultural symbolism partially explain a lack of consistency in results across these studies.

Thus, the aim of this research was to further understand people's preferences and emotional responses to this individual, but important element of nature, i.e. flower colour. Results here will help illustrate how small scale factors, such as flower colour, might affect mood, and thus have implications for longer term psychological health. In a more practical sense, it will allow landscape architects to understand better how flower colour and composition could be used in the landscape to influence psychological health, where this is required, and how different colours may provide alternative benefits to different user groups. The research used images of a naturalistic floral composition style (mimicking that found in a meadow or informal garden setting) to specifically address how flower colour in a garden/designed landscape context 1. Affects preference, 2. Promotes relaxation, 3. Promotes an uplifted emotion and 4. Determines if there is a relationship between preference and these potential health-promoting effects.

2. Methods

2.1. Online questionnaire design and procedure

A questionnaire was designed to capture participants' preference for and positive psychological responses to flower colour (Fig. 1; Appendix A). Both multiple-choice and open-ended questions were used, and there was a section on demographic characteristics, especially factors that may influence participants' perception of designed landscapes or plants (e.g. where they live or how often they garden) (Sang et al., 2016). A series of PSS (Perceived Stress Scale) questions were included as a measure of how stressful participants felt their lives were around the time of the survey. The PSS (Cohen et al., 1983) is a recognised psychological tool for measuring an individual's perception of stress. It is clinically validated and widely used by the UK's national (NHS) and other health services.

Images used within the questionnaire exploited a photomontage technique developed by Wang et al. (2017; 2019) and Deng et al. (2020), and these allow key landscape components to be featured without interference from other extraneous factors. The photomontage images were created in Photoshop CC 2017 (Adobe Inc., San Jose, CA, USA) and were manipulated to meet the following conditions: 1. Each image presented a 'daisy-like' (*Asteraceae*) flower — *Aster* × *frikartii* 'Mönch' — blue, *Osteospermum* 'Margarita Cool Purple' — purple, *Aster ageratoides* 'Starshine' — white, *Gazania rigens* 'Kiss Orange Flame' — orange, *Helenium* 'Ruby Tuesday' — red, *Osteospermum* 'Tresco Pink' — pink, *Helenium* 'Butterpat' — yellow and *Chrysanthemum* 'Spartan Linnet' — brown/maroon. 2. Flower colour was distinguished, by ensuring a dominant hue occupied > 2/3 of the flower's surface, and background hue was green. 3. Perspective angle and number/size of flowers were similar across images 4. The quality and size of images were the same — PPI = 300, resolution = 945px* 945px, with artificial blurring being imposed at edges to represent an 'out of focus' periphery that can occur in genuine photographs. Despite these approaches it was still possible that some variation in clarity, brightness or saturation of the images may have resulted due to the different devices used by participants (screen size, colour settings etc.), but strong differentiation in colour between the options should still have been apparent.

A respondent's preference for a certain flower colour was evaluated by posing the question 'Which of these following plant communities do you like best?' and giving a choice of eight options (Fig. 1). Subsequent questions asked; which plant community do you find the most uplifting and which do you find the most relaxing? Participants were also asked to

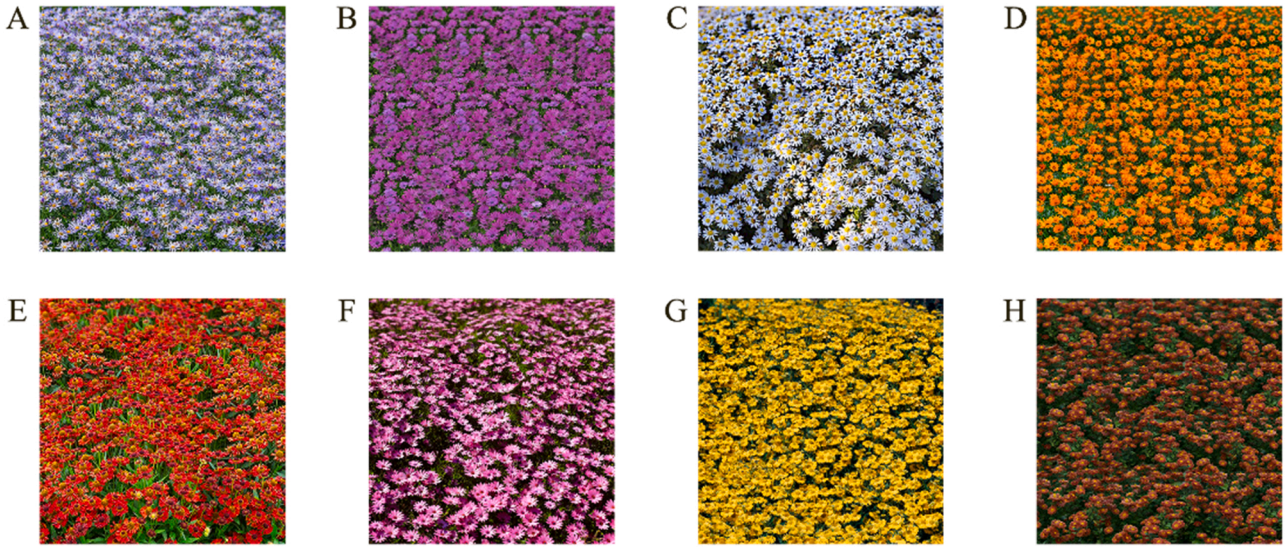

Fig. 1. Flower images in eight different colours. A - blue, B - purple, C - white, D - orange, E - red, F - pink, G - yellow and H - brown.

rank the images in terms of most uplifting, and most relaxing, with rankings being converted to scores for subsequent analyses. i.e. highest rank = 8, lowest rank = 1. If a colour was not given a ranking, it was automatically allocated a value of 1.

The online questionnaire survey was built on the dedicated web-platform SmartSurvey (https://www.smartsurvey.co.uk/), and was available from 20 August-20 November 2020, after ethical clearance and a pilot study was implemented at the University of Sheffield (data not included). An online questionnaire was chosen during this period (rather than in person) due to Covid-19 restrictions being in place, and allowing for a greater number of respondents to complete the survey. Participants were adults ≥ 18 years, resident in the UK and could terminate the questionnaire at any point. Data was treated anonymously. A link to the questionnaire was promoted through emails, websites, social media and other online discussion platforms.

2.2. Online questionnaire data analysis

Statistical analysis was conducted using IBM SPSS Statistics for Windows 26.0 (IBM Corp, Armonk, NY, USA). Continuous variables were described as means with standard errors (SE), whereas categorical variables were presented as frequencies with percentages. On the advice of a statistician, Chi-square tests include Fisher's exact tests and Pearson's chi-square tests ($P = 0.05$ as significance level) were conducted to identify all significant demographic variables. Fisher's exact tests were carried out to examine correlations between people's preferences for flower colours, uplifted emotions and relaxation. Scored data were analysed via ANOVA with Bonferroni post-hoc tests used to differentiate scores based on significant differences ($P \leq 0.05$, different letter in figures indicating whether mean values were significantly different from each other). Further investigations explored the extent to which preference for a colour influenced its capacity to relax or provide uplift for an individual, by comparing the proportions of participants that stated their favour colour was also most relaxing or uplifting. Fisher's exact tests again being used to explore the significance of these relationships.

To find out why people prefer a certain flower colour, an open-ended question "Can you say why?" was followed. Participants' responses to this question were organised into eight files in NVivo 2020 (QSR International Pty Ltd., Doncaster, Australia) based on their favourite flower colour. A word frequency query was run on each file using 'the Wizard' in the software to list the most frequently occurring words in participants' answers. The text match level of the query was adjusted to level 3, meaning that exact words, words with same stem and synonyms (words with a very close meaning) were counted together. For example, words like "bright", "brightly" and "brightness" are all counted as "bright".

3. Results

3.1. Demographic characteristics of the sample

Most respondents (n = 670) were female (76%, Table 1) or fell into the 25–34 or 65 + age groups. The majority of respondents lived in either a suburban or urban environment but considered themselves to have a strong relationship with nature. The questionnaire attracted a large proportion of keen gardeners, with approximately 46% stating they gardened 2–3 times a week or more frequently, with 79% and 61% stating they liked 'very much', plants and flower gardens respectively (Table 1). Most participants considered their stress levels to be low or moderate, with only 11% expressing high-stress levels (Table 1).

3.2. Preference

Based on the images presented in the questionnaire, white floral compositions were the most popular (preferred by 26%), followed by blue (18%) and orange (16%) (Fig. 2). When asked the reasons behind their choice, respondents mentioned the words 'bright', 'happy', 'natural', 'calming' and 'peaceful' when choosing white. Words associated with blue were 'bright', 'calming', 'natural' and 'relaxing'. 'Bright' and 'happy' were also linked with orange, but so were 'warm' and 'uplifting'. Brown was the least preferred flower colour (2%) (Fig. 2).

Table 1
Demographic profile of participants' (n = 670) (percentage of total in parenthesis) and attitudes to plant and health related factors.

Age		**Like Plants**	
18–24	110 (16%)	Like very much	531 (79%)
25–34	151 (23%)	Like	110 (16%)
35–44	95 (14%)	Neither like/dislike	24 (4%)
45–54	85 (13%)	Not very much	4 (1%)
55–64	97 (14%)	Not at all	1 (0%)
65 +	132 (20%)	**Like Flower Gardens**	
Gender		Like very much	411 (61%)
Male	147 (22%)	Like	213 (32%)
Female	508 (76%)	Neither like/dislike	40 (6%)
Non-binary/third gender	9 (1%)	Not very much	6 (1%)
I prefer not to say	6 (1%)	Not at all	0 (0%)
Living Environment		**Stress Level**	
Urban	239 (36%)	Low	154 (23%)
Suburban	330 (49%)	Moderate	445 (66%)
Rural	101 (15%)	High	71 (11%)
Nature Relatedness		**Gardening Frequency**	
Very low	14 (2%)	Rarely/never	143 (21%)
Low	54 (8%)	2–3 times a month	130 (19%)
Moderate	69 (10%)	Once a week	92 (14%)
High	190 (28%)	2–3 times a week	180 (27%)
Very high	343 (51%)	Daily	125 (19%)

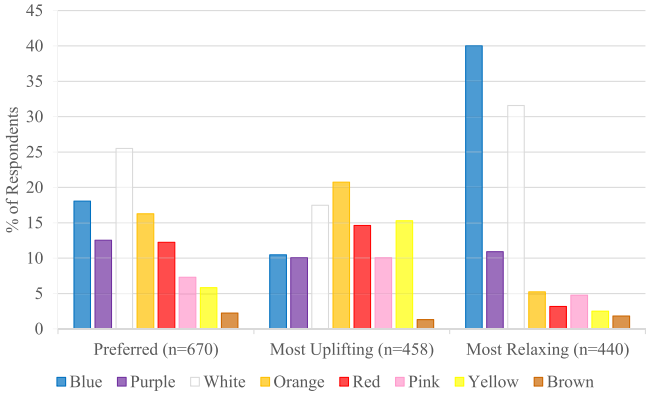

Fig. 2. Percent of respondents who stated the colours they preferred or felt they were most uplifting or relaxing when presented with computer-generated floral compositions, n = number of respondents answering.

The only significant demographic factor affecting colour preference was respondents' age ($P < 0.001$). Over all, white was the most popular colour among all other age groups, except for people aged 55–64 (Table 2). Only 14% of 55–64 year olds cited white as their favourite, whereas red (24%) and blue (23%) were most popular with this age group. In contrast, red was very unpopular with 18–24 year olds, with only 2% stating it as their preferred colour (Table 2).

3.3. Uplifting flower colours

Orange compositions were seen as most uplifting (21%), followed by white (17%), yellow (15%) and red (15%) (Fig. 2). Age again influenced the colours that respondents considered most uplifting ($P < 0.001$). Orange was quoted most frequently by 18–34 year olds, with 35–44 year olds quoting orange and yellow equally, and 45–54 year olds citing yellow, red and white equally (Table 3). Red was most uplifting for those older than 55 (Table 3).

Using scored data for an uplifting response, indicated that the

Table 2
Preferred flower colour. Percentage of participants (n = 670) by age.

	Percent							
	Blue	Purple	White	Orange	Red	Pink	Yellow	Brown
Age								
18–24	13	7	36	24	2	7	9	2
25–34	23	5	26	23	9	8	5	3
35–44	16	21	25	13	11	5	8	1
45–54	19	8	28	14	16	4	7	3
55–64	23	14	14	12	24	8	4	0
65 +	15	20	23	10	15	10	43	4
Total	18	13	26	16	12	7	6	2

Table 3
Most uplifting flower colour. Percentage of participants who expressed an opinion (n = 458) by age.

	Percent							
	Blue	Purple	White	Orange	Red	Pink	Yellow	Brown
Age								
18–24	8	1	20	31	3	16	18	3
25–34	12	10	23	25	7	5	17	0
35–44	5	15	8	23	15	10	23	3
45–54	12	5	19	15	19	9	19	0
55–64	15	7	14	18	25	8	14	0
65 +	9	19	18	13	21	13	6	2
Total	10	10	17	21	15	10	15	1

frequency of gardening had some influence on the results. For those people (46%) who gardened 2–3 times a week or more frequently (defined as 'Frequent', Fig. 3) all colours were seen as equally uplifting, except blue and brown, which had significantly lower scores. Infrequent gardeners though, defined orange as a significantly more uplifting colour than all others except yellow (Fig. 3). Yellow was more uplifting than blue, purple, pink and brown, but not white or red for these infrequent gardeners. Brown had a significantly lower score than all other colours (Fig. 3).

3.4. Relaxing flower colours

Of the whole sample, 76% (507) found the plant communities relaxing. There was also a degree of consensus on the most relaxing colours, with blue (40%) and white (32%) being seen as most relaxing (Fig. 2). Purple (11%) was considered by some as relaxing, but most other colours were rarely considered relaxing, with less than 6% of respondents choosing these colours (Fig. 2).

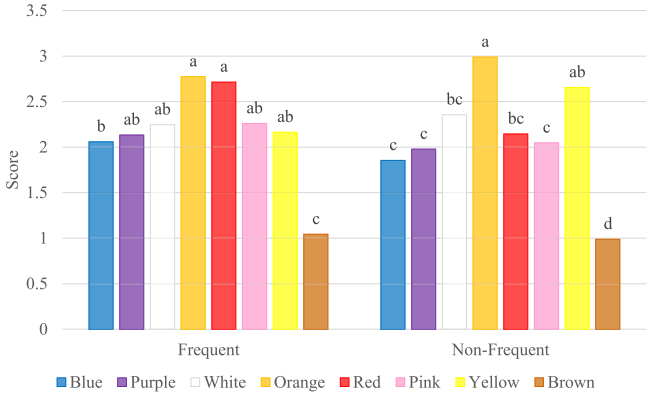

Fig. 3. Scored data for the most 'uplifting' colours as defined by those who gardened frequently (Frequent) and those who did not (Non-Frequent). Letters denote statistical differences within each population ($P \leq 0.05$), so comparisons within a population are valid, for example within the Frequent group orange (a) has significantly greater score than e.g. blue (b), but not purple (ab). Comparisons across the two populations are not valid.

The correlations between respondents' most relaxing flower colours and their demographic factors were examined by Chi-square tests. Fisher's exact test indicated that one demographic factor (living environment) had a significant ($P < 0.001$) association with respondents' perception of the most relaxing colour. In urban and suburban environments, approximately equal numbers of respondents thought blue and white were relaxing (Table 4), whereas, in the rural population, blue (54%) was considered more relaxing than white (18%).

Scored data showed no difference (P = 0.86) between frequent and non-frequent gardeners in terms of relaxation, and blue and white were again seen as significantly more relaxing than other colours (Fig. 4). In both groups, purple was deemed more relaxing than red, yellow or brown (Fig. 4).

3.5. Relationships between self-expressed preference, uplifted emotions and relaxation

Not all respondents indicated a most uplifting or a most relaxing colour in the questionnaire, but about 2/3 of the total population did. Comparisons for these respondents were carried out with respect to their preferred colour. A Fisher's exact test detected a strong link between respondents' preferred flower colour and the most uplifting flower colour (n = 458, $P < 0.01$). The link was relatively consistent, with 54% choosing the same flower colour as their preferred option. A high consistency was applied to all eight different flower colours (Fig. 5). Interestingly, colours of flowers that are not usually classified as uplifting, such as blue and purple, also delivered strong uplifting responses in those who preferred them (Fig. 5).

Among the eight different flower colours, orange had the highest uplifted emotion score, 2.89 ± 0.12 (mean ± standard error; specific data not shown, but refer to Fig. 3 for colour comparisons as defined by frequency of gardening), but this was still significantly less than the score respondents attributed to their preferred colour (mean 3.82 ± 0.14), again suggesting that a favourite colour (irrespective of the actual colour) was strongly linked to positive emotions. Similarly, respondents rarely considered a colour uplifting (1.91 ± 0.06) if it was a colour they did not prefer.

A Fisher's exact test detected a significant correlation between

Table 4
Most relaxing flower colour. Percentage of participants who expressed an opinion (n = 440) by living environment.

	Percent							
	Blue	Purple	White	Orange	Red	Pink	Yellow	Brown
Living Environment								
Urban	39	5	35	7	2	5	3	4
Suburban	37	15	33	4	1	5	3	1
Rural	54	9	18	4	12	1	1	0
Total	40	11	32	5	3	5	3	2

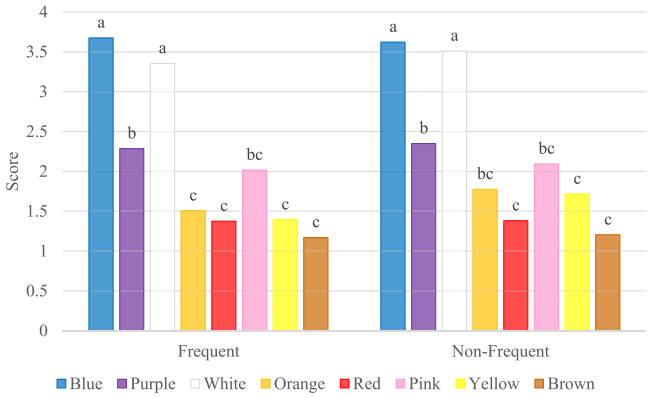

Fig. 4. Scored data for the most 'relaxing' colours as defined by those who gardened most frequently (Frequent) and those who did not (Non-Frequent). Letters denote statistical differences within each population (P ≤ 0.05), so comparisons within a population are valid, for example within the Frequent group blue (a) has significantly greater score than e.g. purple (b), but purple is not significantly greater than pink (bc). Comparisons across the two populations are not valid.

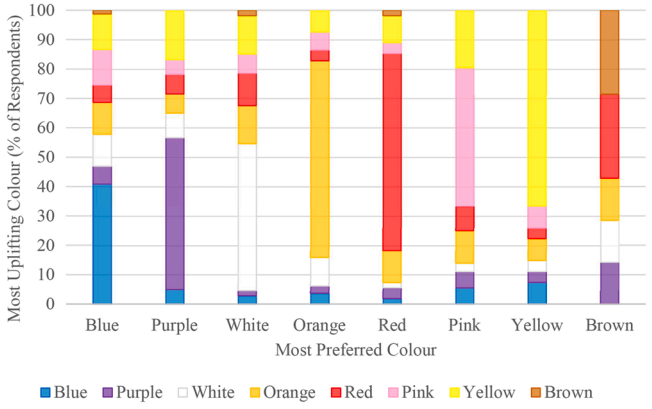

Fig. 5. The relationship between respondents (n = 458) preferred colour (x axis) and the colour they find most uplifting (y axis). Data based on a percentage basis. So of the respondents who cite e.g. blue as their preferred colour, 40% of these consider blue to be the most uplifting colour.

respondents' preferred flower colour and the one they found most relaxing (n = 440, P < 0.001). Consistency was studied by comparing their choices. More than half of the respondents (57%) chose the most relaxing colour in line with their preferred flower colour. The extent to which respondents saw their favourite colour as relaxing though, varied with the colour (Fig. 6). Amongst those respondents who preferred blue, 93% considered it relaxing; likewise, for white, 77% thought it was relaxing and similarly 56% of respondents who preferred purple considered that relaxing. Pink too, was considered relaxing for many of those (44%) who preferred it (Fig. 6). Conversely though, high proportions of respondents who preferred orange, red and, to some extent,

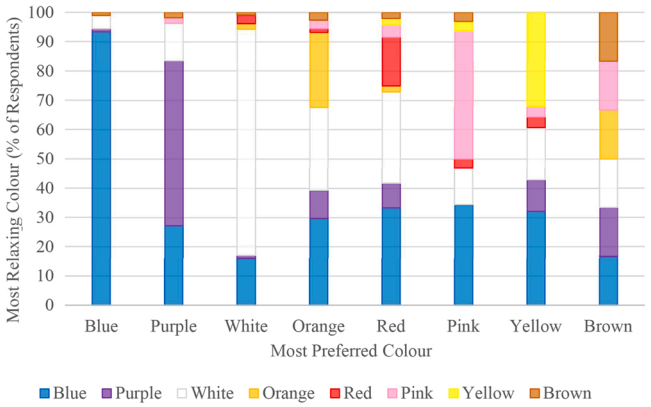

Fig. 6. The relationship between respondents (n = 440) preferred colour (x axis) and the colour they find most relaxing (y axis). Data based on a percentage basis. So of the respondents who cite e.g. red as their preferred colour, approximately 16% consider red as most relaxing, but 33% of this population consider blue the most relaxing colour.

yellow, quoted blue as the most relaxing (Fig. 6).

Examination of the score data confirmed blue (3.65 ± 0.13) and white (3.44 ± 0.13) as the most relaxing colours (specific data not shown, but refer to Fig. 4 for colour comparisons as defined by frequency of gardening). Although these were significantly higher than other colours, they were still lower than the mean relaxation score many respondents gave their preferred colours (3.79 ± 0.14). As before, a less favoured colour was deemed to have a low relaxation value (mean = 1.92 ± 0.06) irrespective of colour; a significantly lower value than the preferred colour.

Notably, a further Fisher's exact test detected a significant correlation between respondents' most uplifting flower colours and the most relaxing flower colours (n = 390, P < 0.001). Overall, 32.3% of respondents chose the same flower colours for both uplifting their emotions and relaxing them (data not shown). White was chosen by 42 individuals as both the most uplifting and most relaxing flower colour (data not shown). Similarly, 34 people cited blue as the colour that both provided them with the greatest uplift and the greatest feelings of relaxation (data not shown).

4. Discussion

4.1. Emotional responses

Blue and white were deemed the most relaxing flower colours when presented as informal drifts of a single colour (as depicted by semi-natural plant community presented within a digital format). Self-reporting ranking and subsequent scoring showed these colours to be significantly more relaxing than other colours presented to the participants. This empirical data aligns with insights and anecdotes for these flower colours being useful in in vivo therapeutic landscapes to promote relaxation (Pavlova, 2015) including other studies that employed virtual images (Li et al., 2012). This study, therefore, indicates that blue and

white flowers can be used alongside green foliage to create an overall relaxing plant composition in the landscape. Landscapes that induce feelings of calmness and relaxation potentially having a role to play in alleviating physiological stress (Berto, 2014; Abraham et al., 2010; Chalmin-Pui et al., 2021b) with implications for longer-term health benefits (e.g. Teismann et al., 2019: Stogner et al., 2020).

Flowers may affect our emotions additionally though, by lifting the spirits and creating positive responses such as excitement and wonder, so-called positive affect responses (Richardson et al., 2016; Cameron et al., 2020). White fell into this category too, although orange was considered the colour that gave the overall strongest uplifting effect. Orange being scored significantly greater than white for example, in those who gardened less frequently (Fig. 3). In this group, yellow flowers were also seen as strongly uplifting. Those who gardened more frequently, however, had a wider range of colours they considered 'uplifting', with only brown scoring very poorly. Here too, orange, but also red, had significantly higher scores than blue (Fig. 3). The impact of positive affect (uplift) induced by the natural world on mental health is still understudied, but it is argued that short periods of positive emotion (especially if experienced on a frequent basis) influences longer-term mental health (Bratman et al., 2015; Richardson et al., 2016). Arguably, viewing uplifting and stimulating floral colours and inducing positive affect is one of a number of experiences that can help provide resilience against mental health problems. If so, then those 'warmer' colours used in public landscapes and private gardens may not only provide instantaneous positive impact (sometimes called the 'wow' factor) (Wilson, 2011; Jang et al., 2014; Pavlova, 2015; Paddle & Gilliland, 2016; Hoyle et al., 2017) but may also enhance well-being over a longer term. Therefore, floral displays that comprise orange, white, yellow and red should not be ignored by designers of therapeutic landscapes, and that these colours may contribute, albeit through a different mechanism, to maintaining positive mood with implications for retaining/restoring good mental health. Research in Sweden indicates that patients who have suffered trauma, experience a recuperation journey, but they seek different forms within, and experiences from, the landscape at subsequent stages of that 'journey' (Stigsdotter and Grahn, 2011; Pálsdóttir et al., 2014). In effect viewing, serene, calming cool colours (blue, purple, green) may be important early on in a restorative process, whereas later on brighter, warmer colours (orange, yellow, red) have a part to play in restoring a positive mood. Landscape architects should reflect on this when designing therapeutic landscapes, but also take note there are also subjective influences that may also influence these responses (see points below about colour preference and restorative experiences).

4.2. Preference

The research aimed to better understand how flower colour affected preference when flowers were presented as a semi-natural meadow-like community, but without any additional interfering factors or visual intrusions. Overall, the data showed that there were strong differences in the colours preferred by the participants. White was the most popular (26%) with flower colours of blue (18%) and orange (16%) ranked next. Our results partially agree with previous studies that cite white and blue as popular colours both within wider contexts (Palmer & Schloss, 2010; Fortmann-Roe, 2013; Pavlova, 2015) and research involving flowers (Pavlova, 2015, including those involving similar online methods, Hůla and Flegr, 2016, 2020). Nonetheless, it was surprising that white was chosen by more participants than other colours, particularly blue; the latter often being recorded as the most popular colour even within floral studies (Palmer and Schloss, 2010; Fortmann-Roe, 2013; Hůla and Flegr, 2016). A possible simple explanation for this may relate to white being omitted in many previous flower/garden studies. To date, only Hůla and Flegr (2016) seem to have experimentally compared people's preferences for blue and white flowers in natural environments. Results presented here conflict with their data (where blue was most popular), possibly due to the different rating methods used. Hůla and Flegr (2016) compared coloured and sepia tone versions of the same flowers to study the effects of specific colours, but there was no sepia sequence with white which may have under-represented the popularity of white in their study. Interestingly, although white was found to be the most popular colour overall here, it was not universally so across the age ranges of participants. For the 55–64 years old age group red was preferred.

Another finding that challenged previous thinking was the popularity of orange as a floral colour. This has not been evident before in both general studies or those on flowers (Eysenck, 1941; Ellis and Ficek, 2001). In this study, a component of the population reported orange as being bright', 'happy', 'warm' and 'uplifting'. The reason for orange being relatively popular is unclear, but may relate to the context being naturalistic, informal plantings, as in recent years, orange flower species such as *Eschscholzia californica* and *Calendula officinalis* have become more evident in such flower communities. Perhaps more people are associating this type of landscape with the colour orange, and appreciating the aesthetic effect.

Overall the results differed from studies on cut flowers (Behe et al., 1999; Yue and Behe, 2010) which suggest that red and pink are the most, and blue and yellow the least, preferred florist shop flowers. Thus, it is conceivable that preference for flower colour is influenced strongly by context, and/or cultural associations (red and pink cut flowers, for example, being associated with romantic gestures and giving cut flowers as gifts; Yue & Behe, 2010).

Brown and yellow were the least popular colours in this study. These may align with the habitat selection (Heerwagen and Orians, 1993) and ecological valence (Palmer and Schloss, 2010) theories, which both suggest people tend to dislike brown and some shades of yellow because they are related to faeces, death, dead vegetation or drought. Irrespective of this, results here may partially be due to the hue and saturation of yellow used (a moderate- dark hue compared to some other *Asteraceae* frequently used in the designed landscape, e.g. *Helianthus* 'Lemon Queen' with a lighter, brighter yellow). Overall though, context seems important for colour preference, orange was a relatively popular flower colour here, but rarely expressed as a favourite colour in general (Silver et al., 1988; Jonauskaite et al., 2019). This corresponds with Schloss et al. (2013) who state that individuals vary in their preferences for different types of coloured objects.

4.3. Preference in relation to mood

An additional question was to what extent did preference for a given flower colour potentially influence any health-promoting response. "A little bit of what you fancy does you good" (Lloyd Marie – singer 1870–1922) may be the philosophy here, as the data suggested significant correlations between flower colour preference and both what individuals viewed as most relaxing, or most uplifting. What's more, a large proportion of people indicated that their preferred flower colour was able to relax them, but also provide an uplifting response. This seems counter-intuitive, but may relate to the way people are interpreting the term 'uplifting'; perhaps seeing it as 'improving mood' in a general sense rather than specifically arousing, exciting or stimulating. It is feasible though that colours can be seen as both relaxing and uplifting. White flowers fell into this category. Further research is required to clarify these points. Overall though, the datasets support our hypothesis that higher preferences for flower colours are found to be associated with positive psychological effects (both uplift and relaxation). Herzog et al. (2003) assumed that preference, although conceptually distinct from restoration, might play a role in attracting people to, and retaining them for longer within, restorative environments. This study of flower colour provides some support for this, as the data suggests participants are more relaxed when viewing flower colours they prefer. This may relate to environmental preferences being linked to compatibility with (Kaplan & Kaplan, 1989), or possessing functional

significance for (van den Berg et al., 2003), the perceiver. Thus it would seem that the restorative effects of flowers are due more to environmental preferences (van den Berg et al., 2007) rather than habitat selection (Heerwagen and Orians, 1993) or ecological valence (Palmer and Schloss, 2010) theories.

White was the most popular colour in this study and ranked second in both terms of relaxation and uplift. Thus if a landscape architect was restricted to the use of a single flower colour within a therapeutic environment, white would be the colour to recommend. This contradicts Xie et al. (2021) who found white flowers reduced cheerfulness and relaxation compared to red or yellow flowers. The reason for this is not clear, but may relate to different visual stimulations (cut roses arranged in glass vases) or cultural context (participants based in China). Therefore, it is possible that the psychological effect of flower colour is also influenced by context and geographical region (Neale et al., 2021).

4.4. Limitations of the study

The study was conducted during the Covid-19 pandemic lockdown, so the research was carried out entirely on-line. There was no opportunity to verify results from in vivo field studies or in person lab studies, and these should be carried out in future to verify the results reported here. The data is skewed towards female participants and further work should investigate further how gender or ethnic background affect some of the results reported. Also, results here report the responses to hue, but saturation and brightness of a given hue may also impact emotional and health-related parameters (e.g. see points about yellow above); we did not control for these when randomly selecting the plant genotypes. Moreover, due to variations between devices employed by participants we could not be sure that they necessarily viewed the same brightness or saturation for each colour presented. Future research should account for these aspects of colour too.

5. Conclusions

The data presented suggests that two phenomena determine the psychological benefits associated with flower colour. The first is that there is some 'universal truths' associated with certain floral colours – flowers in white, blue (and to a lesser extent – purple) can play an effective role in relaxation; and flowers in white and warm colours such as orange, yellow and red can evoke uplifted emotions and deliver better positive affect. The second phenomenon though, suggests that additionally and independently, an individual preference for a particular given colour can also elicit positive psychological benefits, irrespective of what that particular colour is. So, for example if an individual likes the colour purple, that individual will find this colour uplifting, even though the vast majority of people who prefer other colours will not find purple uplifting. This suggests that beneficial psychological influences associated with flower colours are both determined by objective factors ('cool' colours relax – 'warm' colours promote positive affect) and a subjective factor (the extent to which an individual likes or is drawn to a particular colour). This has significance for landscape architects in that certain flower colours can be used to specifically promote therapeutic responses in appropriate locations, but that components of any designed landscape should still take account of personal responses and preferences. In practice, this might mean that a widely used area of a therapeutic garden is dominated by blue (to provide a relaxing, soothing feel for the majority of visitors), but other more 'intimate', peripheral areas could be designed around other colour themes to meet more personal preferences. Thus retaining a variety of flower colours in the landscape is still important, not only from a health and well-being perspective, but also for wider cultural ecosystem services.

This research studied people's response to single colours, but gardens and other therapeutic landscapes are usually composed of mosaics of different flower colours. Thus, future research by this group will evaluate how colour combinations influence psychological responses.

CRediT authorship contribution statement

Liwen Zhang: Conceptualization, Methodology, Software, Validation, Formal analysis, Investigation, Resources, Data curation, Writing – original draft, Writing – review & editing, Visualization, Supervision, Project administration, Funding acquisition. **Nicola Dempsey:** Methodology, Supervision, Writing – review & editing. **Ross Cameron:** Conceptualization, Methodology, Validation, Formal analysis, Writing – original draft, Writing – review & editing, Supervision, Funding acquisition.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data Availability

A summary of the results will be placed within University of Sheffield PhD data repository.

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Appendix A. Supporting information

Supplementary data associated with this article can be found in the online version at doi:10.1016/j.ufug.2022.127795.

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