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# Measuring perceived beauty of the Great Barrier Reef using eye-tracking technology

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## ABSTRACT

The purpose of this research is to test the usefulness of eye-tracking in measuring the perceived beauty of photos of the Great Barrier Reef. Eye-tracking is used to measure visual attention (fixation count, fixation duration) to 21 photos ranked in the degree of perceived beauty. Results indicate significant differences in visual attention to 'beautiful' and 'ugly' photos and a significant correlation between average perceived beauty and attention measures. This study provides evidence that eye-tracking can be used to measure the relative perceived beauty of natural images reflecting the attention given to 'attractive' images.

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## KEYWORDS

Aesthetics; perceived beauty; attention; eye-tracking; Great Barrier Reef; World Heritage

## Introduction


The importance of aesthetic characteristics of a destination is well recognized in tourism literature as natural beauty is one of the key reasons for tourists to visit a place (Kirillova, Fu, Lehto, & Cai, 2014; Todd, 2009; Yoon & Uysal, 2005). The aesthetic qualities of a destination affect tourists' experience in that place, their satisfaction, loyalty and revisit intentions (Chi & Qu, 2008; Lee, Jeon, & Kim, 2011; O'Leary & Deegan, 2003; Tan & Kuo, 2014). Indeed, tourist perceived beauty of a destination plays a critical role in destination choice process (Vogt, Fesenmaier, & MacKay, 1994). For example, UNESCO World Heritage Listed Regions such as the Great Barrier Reef (GBR) attracts millions of tourists to North Queensland because of their aesthetic reputation (Johnston, Smith, & Dyke, 2013; Packer, Ballantyne, & Hughes, 2014).

The GBR Marine Park application for listing as a World Heritage Area states that it is a region of 'natural beauty' that 'contains superlative natural phenomena or areas of exceptional natural beauty and aesthetic importance' (Great Barrier Reef Marine Park Authority, 2014, p. 93). This natural beauty extends 'above and below the water' (Great Barrier Reef Marine Park Authority, 2014, p. 280). However, The Great Barrier Reef Outlook Report 2014 (Great Barrier Reef Marine Park Authority, 2014, p. 100) indicates the underwater beauty of the GBR is under threat due to a reduction in coral cover and reduced water clarity.

The [GBR] Region generally continues to be an area of great natural beauty; however, coastal infrastructure, marine debris [especially on beaches], reduced water clarity and declining coral cover, especially in southern and central inshore areas, have reduced underwater aesthetic values.

Given the importance of maintaining the natural beauty of places such as the GBR, it is somewhat surprising that there is no agreed approach to evaluating perceived beauty. Some prior work has

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made recommendations, but no objective assessment method is as yet available (Context Pty Ltd, 2013). Development of an objective approach to the measurement of perceived beauty would enable aesthetic assessments to be included into destination management and conservation planning, allowing changes in the beauty of the GBR to be monitored (Marshall, Marshall, & Smith, 2017). This paper reports on research conducted to develop an objective method to monitor the perceived underwater scenic beauty of the GBR.

The method is based on the idea of beauty as a subjective mental evaluation of a perceived object (i.e. a visual scene or picture) (Berlyne, 1973; Lothian, 1999). Individual aesthetic evaluations of an object will differ due to variations in expertise or preferences, but an individual's evaluation of an object's beauty is correlated to subconscious visual attention processes and the eye-movements they direct (Calvo & Lang, 2004; Nummenmaa, Hyönä, & Calvo, 2006). Such eye-movements can be tracked, and their important characteristics such as fixations and saccades, measured using eye-tracking equipment (Leder, Mitrovic, & Goller, 2016; Scott, Zhang, Le, & Moyle, 2017). Therefore, certain characteristics of an individual's eye-movements when exposed to a series of images provide an indicator of the subject's relative aesthetic evaluation of those images.

The aim of this paper then is to provide a method for evaluating the relative beauty of a series of images of the coral, fish and other underwater characteristics of the GBR. The method was tested by examining the relationship between eye-tracking measures and respondent beauty scores. Specifically, sixty-six respondents were asked to rank the beauty of 21 underwater photographs on a 10-point scale. The averages of these rankings were correlated with visual attention measures of the same images obtained using eye-tracking methods in a laboratory setting (Scott, Green, & Fairley, 2016). The paper contributes to the literature by demonstrating the potential of using eye-tracking technology in aesthetic research: significant correlations between average perceived beauty rankings and average eye-tracking measures were confirmed.

## Literature review

### *Aesthetic experience and beauty*

The conceptualization of beauty may be grouped into objective and subjective approaches (Lothian, 1999). The first considers that beauty is an objective and intrinsic characteristic of an object. In this view beauty is 'an aspect of the experience of idealisation in which an object(s), sound(s), or concept(s) is believed to possess qualities of formal perfection' (Hagman, 2002, p. 661). Interaction with, or experience of, objects with this property leads to recognition of their intrinsic beauty. Indeed the ability to recognize beauty is an important human capacity, and the 'subjective experience of beauty leads to a sublime and exalted state that is unique, psychologically significant and desirable' (Hagman, 2002, p. 661). The sense of beauty is often found in nature and associated with a feeling of wholeness, pleasure, a lessening of anxiety, awe, joy, excitement, relaxation and contentment (Kirillova & Lehto, 2016; Lynn, Chen, Scott, & Benckendorff, 2017; Todd, 2009).

The phrase 'beauty is in the eye of the beholder' reflects an alternative subjective approach to the conceptualization of beauty. This means that an object can have no objective property of beauty and that it is the person's perception and interpretation of the object that determines its perceived beauty. This subjective view considers that recognition of beauty is 'a pleasure which is experienced through the perception of an object' (Lothian, 1999, p. 190). This study adopts the subjective approach to beauty treating it as a human reaction that varies across different viewers and cultures (Hekkert & Leder, 2008). Such human reactions are measurable and such measurements can provide an objective measure of 'beauty'. This second approach is consistent with the empirical aesthetics of Berlyne (1973) whereby neuroscientific evidence is considered to strengthen, complement, and constrain explanation of beauty at the psychological level (Cela-Conde, Agnati, Huston, Mora, & Nadal, 2011; Leder & Nadal, 2014). Thus, the perceived beauty of a landscape is derived from perceptual responses of respondents (Kara, 2013; Karmanov, 2009).

Compared to beauty, the more general term of aesthetics deals with the 'experience of objects which provide the consumer with an element of beauty' (Charters, 2006, p. 239). Therefore, objects which are perceived as beautiful are experienced as pleasurable through an aesthetic process. This aesthetic experience of human beauty influences subsequent judgements, favouring the beautiful. (Lindell & Lindell, 2014). Hence, objects, or images, which are pleasing to the eye, are of considered of higher value in terms of their aesthetic beauty (Haas et al., 2015). In this way, the concept of perceived beauty is similar to attractiveness (Lindell & Lindell, 2014, p. 768).

Prior research has found that aesthetic appreciation of art relies on the brain's reward processes involved in reward representation, prediction and anticipation, affective self-monitoring, emotions, and the generation of pleasure (Leder & Nadal, 2014). This suggests that reward (i.e. wanting the aesthetic experience) triggers aesthetic preference, judgment, and subsequently decision (Leder, Belke, Oeberst, & Augustin, 2004; Reimann, Zaichkowsky, Neuhaus, Bender, & Weber, 2010). Cognitive appraisal describes the process by which individuals evaluate whether an encounter with the environment is relevant to their well-being (Lazarus, 1991). The type and intensity of aesthetic response to an object depend on the degree of expertise of the viewer. In a comparison of experts and non-experts (measured by facial EMG and several rating scales), experts gave distinctively different evaluations, not only to the artworks but also to a control set of emotional images (Leder & Nadal, 2014). This suggests that expert evaluations of scenery and images may vary from those of lay people. The aesthetic evaluation processes that allow the identification of an object as having the attribute of beauty are based on sensory (usually visual) perception (Ross, 2016). Human visual perception allows attentional processes a major function in selecting relevant stimuli for detailed examination (Nummenmaa et al., 2006).

### ***Tourism and beauty***

Beauty is recognized as an important characteristic of tourism destinations and experiences (Beza, 2010; Breiby & Slåtten, 2015; Horng, Chou, Liu, & Tsai, 2013; Kirillova et al., 2014; Kirillova & Lehto, 2016; Knudsen, Metro-Roland, & Rickly, 2015), albeit from a traditionally British perspective (Andrews, 1989). Beauty is often associated with natural scenery (Beza, 2010), emotional reactions (Breiby & Slåtten, 2015), and subsequently benefits including restoration (Kaplan, 1995). Breiby (2014, p. 171) found that experts considered that the aesthetics of nature-based tourism involved key concepts of 'perception, structure, senses, beauty, and pleasant'. However, as in the literature of consumer behaviour (Patrick & Peracchio, 2010), psychology (Arnheim, 1966; Leder & Nadal, 2014) and nature research (Carlson, 2009), the principal perspective on aesthetic appreciation found in the tourism-related literature is objective in nature, that is that the beauty of a scene is connected to the characteristics of a destination rather than the observer's evaluation (Kirillova, 2015; Kirillova et al., 2014; Kirillova & Lehto, 2016).

Again, despite the importance of sun and sea tourism, the literature of marine aesthetics and coral reefs is restricted (Cracknell, White, Pahl, & Depledge, 2017; White et al., 2010). Pocock (2002) and Johnston and Smith (2014) have discussed the aesthetic values of the GBR highlighting the significance of beauty for World Heritage listing. Other studies have looked at people's preferences for, affective responses to, and the restorative potential of, different types of public aquaria exhibits (Cracknell et al., 2017). Dinsdale (2009) showed that human visual evaluations provided a consistent judgment of coral reef status regardless of their previous knowledge or exposure to these particular ecosystems. There is evidence that the evaluations of images of the pristine or damaged coral reefs can be in terms of pleasant or ugly. Coral reef photographs are associated with the 'good' end of the evaluation dimension (Dinsdale, 2009).

In summary, the beauty of a photo is considered here a personal judgment based on pleasant emotional reactions to the photo. The perception of beauty causes a reorientation of attention towards the object that is perceived as beautiful. Therefore, the study proposes that there will be

significant correlations between attention to and perceived beauty/ugliness of images of underwater coral reefs and scenes. The following hypotheses are to be tested:

H1: Viewers will pay more attention (measured by fixation count, fixation duration and total time visit) to beautiful pictures than ugly pictures of natural scenes.

H2: There is a significant relationship between eye-tracking measures (fixation count, fixation duration and total time visit) and perceived beauty of natural scenes.

## Methodology

There have been a number of methods used to study the perceived pleasantness or aesthetic reaction to landscape scenery and underwater images. These include photograph viewing and rating of pleasantness (Cracknell et al., 2017; Locher, Krupinski, Mello-Thoms, & Nodine, 2007) evaluations of attractiveness and emotion (White et al., 2010), and use of psychophysical approaches to assessment of aesthetic quality of natural environments (Chang, Hammitt, Chen, Machnik, & Su, 2008). Existing methods used to determine scenic preference often depend on rating the perceived beauty of an image holistically or in terms of presence or absence of visual elements such as buildings or trees (DEHP, 2017). Photo rating is a standard method with a long tradition in both landscape architecture and environmental psychology and is useful when looking at components of a scene (Van den Berg, Koole, & Van der Wulp, 2003).

More recently, eye-tracking techniques have been used for the assessment of landscape characteristics (Nordh, 2012). Eye-tracking techniques can measure visual attention processes in terms of the number or duration of eye-fixations on images. Eye-tracking has been used to measure preferential attention to emotional pictures (Calvo & Lang, 2004) and videos (Teixeira, Wedel, & Pieters, 2012). These studies indicate that an emotional picture, either pleasant or unpleasant, is more likely to be fixated than a neutral picture (Simola, Le Fevre, Torniainen, & Baccino, 2015). Emotional pictures capture attention during the early stages of picture processing by our brain (Nummenmaa et al., 2006). Similar effects have been observed between facial attractiveness and fixation duration (Leder et al., 2016). Similarly, EEG studies indicate that attention is captured automatically by emotional images (Hajcak, MacNamara, & Olvet, 2010). A recent meta-analysis shows an attentional bias for positive as compared with neutral stimuli (Pool, Brosch, Delplanque, & Sander, 2016). Empirical research has noted differences in attention as measured by eye fixations to pleasant and unpleasant scenes (Calvo & Lang, 2004). Interestingly, eye-tracking studies have noted that expert and lay viewers look at different parts of a landscape scene (Dupont, Antrop, & Van Eetvelde, 2015). This study uses two methods to evaluate 21 images of underwater reef scenes; eye-tracking provides a measure of attention while self-completion questions were used to rate images and obtain an average beauty rating of each picture. This will allow the correlation between these two methods to be established. Each of the variables to be measured is discussed below.

*Image rating:* There are varieties of different measurement items used to evaluate the perceived beauty of a scene or image. These include ratings of pleasantness (Locher et al., 2007) and beauty (Arriaza, Cañas-Ortega, Cañas-Madueño, & Ruiz-Aviles, 2004). For example, (Beza, 2010) used a bipolar rating scale, based on the semantic differential of 'beautiful' and 'ugly'. The overall ranking of perceived beauty (rather than about aesthetic dimensions of beautiful scenes) is measured by questions about attractiveness or beauty (Cracknell et al., 2017; Tan & Kuo, 2014; Wang, Zhao, & Liu, 2016). A 10-point scale is common in aesthetic research (Cracknell et al., 2017; White et al., 2010) which provides comparable and transferable data in comparison with other 5- or 7-point scales (Dawes, 2008). Hence, a self-report item was used in this study evaluating the beauty of each picture (1-Not beautiful at all, 10-Very beautiful).

*Attention and beauty:* Eye tracking is a useful technique for objective measurement of attention (Scott et al., 2017) by determining when an individual's eye pauses to examine or interpret a component of an advertisement or image (Rayner, Rotello, Stewart, Keir, & Duffy, 2001). Eye-tracking

has been used to measure preference for advertising (Scott et al., 2016), and interest in parts of a landscape image (De Lucio, Mohamadian, Ruiz, Banayas, & Bernaldez, 1996). The number of discrete fixations (in a given region over the course of scene viewing) is related to the rated informativeness of the region, with regions rated more informative receiving more fixations (Henderson & Hollingworth, 1999). In the present study, the fixation count, fixation duration and total time visit were used to measure attention, considered here as to the degree of attraction for the observer (i.e. a measure of beauty).

*Procedure:* The study was conducted in April and May 2017 under the ethical approval GU 2017/537. Respondents provided informed consent before their participation. Tobii T60 Eye Tracker model 2013 equipment was used to collect eye-tracking data. Respondents sat in a chair in an upright position and viewed images on a computer monitor in a quiet laboratory. A convenience sampling method was applied to facilitate data collection. Sixty-six participants were recruited after a calibration process in order to exclude subjects with eyes problems. During the calibration procedure, subjects were asked to look at specific points on the screen, also known as calibration dots while their eye movements were collected and analyzed ('Tobii Pro online guidelines,' 2019). Next, participants were asked to look at images of the GBR. Participants were free to look at each picture on the screen as long as they want during which time their eye fixations were recorded. The order of pictures was randomized to avoid any possible effect related to picture order. After viewing a picture, respondents rated the picture beauty on a 10-point scale (1-Not beautiful at all, 10-Very beautiful).

*Analysis:* The Tobii eye-tracker provides a record of the direction of the respondent's gaze some 60 times per second and 'maps' this onto a location on the image being viewed. Subsequently, these mapped points were analyzed to determine fixation count and duration data. In the study, the criteria for fixation was 200 ms which is the standard in eye-tracking research (Jacob & Karn, 2003; Pan, Zhang, & Smith, 2011; Wang & Sparks, 2016). Eye-tracking data including fixation count, fixation duration, and total time visit were estimated by Tobii eye-tracking software. The eye-tracking data and image beauty evaluations for each photo were then exported to IBM SPSS version 24 where t-tests and correlation analyses were conducted. All pictures used in the eye-tracking experiment, their average beauty scores and heat maps showing participants' attention are provided in the appendix.

## Results

Descriptive statistics were used to analyse the demographic profile of the whole sample of respondents ( $n = 66$ ) (Table 1). A reasonable balance was achieved between male and female respondents. Most subjects were under 35 years old (63 participants) and are students (59 participants).

The research hypotheses were tested through several steps of data analysis. First, the scores for the 21 selected pictures were grouped and their average beauty scores used to identify beautiful (beauty scores  $\geq 5$ ) and ugly pictures (beauty scores  $< 5$ ). The results show that 13 pictures were

**Table 1.** Characteristics of participants in the eye-tracking experiment.

Characteristics	Number
Gender	
Male	31
Female	35
Age (years)	
18–25	53
26–35	10
36–45	3
Profession	
Student	59
Staff	6
Managers	1
Others	0

**Table 2.** Independent *T*-test of picture groups (beautiful versus ugly).

	Pbeauty	N	Mean	Std. Deviation	Std. Error Mean	Independent samples test	Levene's test Sig. ( <i>p</i> )	<i>T</i> -test Sig. (2-tailed)
PFDuration	≥5	8	7.56	1.773	.627	Equal variances assumed	.211	.001
	< 5	13	5.16	1.131	.314	Equal variances not assumed		.006
PFCount	≥5	8	28.14	5.106	1.805	Equal variances assumed	.139	.001
	< 5	13	20.07	3.754	1.041	Equal variances not assumed		.002
PTimeVisit	≥5	8	7.9242	1.90587	.67383	Equal variances assumed	0.173	.001
	< 5	13	5.4317	1.18105	.32756	Equal variances not assumed		.007

Note: PBeauty: Picture beauty scores rated by participants (from 1 to 10 points). PFDuration: Fixation duration in the picture (i.e. the average length of all fixations during all recordings in the whole picture). A longer fixation means that the object is more engaging in some way. PFCount: Fixation count in the picture (i.e. the average number of fixations in the picture). PTimeVisit: Total time visit for a picture (i.e. the average time participants spent looking at a picture).

rated as ugly and 8 pictures were considered as beautiful. An independent *t*-test was conducted to determine whether there is a significant difference in the eye-tracking measures between beautiful and ugly photos. All eye-tracking measures were significantly different between two groups of pictures. Beautiful pictures have higher means for three eye-tracking measures including picture fixation duration, picture fixation count and picture total time visit in comparison with ugly pictures (with beauty rating under 5) (Table 1). This initial result confirms hypothesis 1 that beautiful pictures attract more attention than ugly pictures.

Next, a correlation analysis was conducted to verify whether self-report beauty evaluation and eye-tracking measures are correlated (Table 2). The results indicate that eye-tracking measures (i.e. fixation count, fixation duration, total time visit) were significantly correlated with picture beauty rating. Results of correlation analysis provided a basis for the next step of testing regression models to verify the relationship between eye-tracking measures and perceived beauty.

Three regression models were separately conducted using the three eye-tracking measures that were correlated with picture beauty (Table 4). Because picture fixation duration, picture fixation count and picture total visit time were also correlated (Table 3), they were not included in the same regression model. All three single regression models were found to predict picture beauty. Of the three eye-tracking measures, picture fixation count is the most reliable indicator of picture beauty explaining 45.1% of variations in picture beauty (Adjusted  $R^2 = 0.451$ ,  $p < 0.01$ ). Hence, tourist attention paid to a natural picture as measured by eye-tracking device reflects their beauty evaluation. Based on this, hypothesis 2 is confirmed.

**Table 3.** Correlations between averages of variables (all pictures).

	PBeauty	PF duration	PF count	PTime visit
PBeauty	1	0.613*	0.692**	0.603**
PFDuration		1	0.968**	0.999**
PFCount			1	0.966**
PTimeVisit				1

\*Correlation is significant at the 0.05 level (2-tailed).

\*\*Correlation is significant at the 0.01 level (2-tailed).

**Table 4.** Single regression models of picture beauty using eye-tracking measures.

Model		Model summary		Unstandardized coefficients	Coefficients Sig.
		Adjusted <i>R</i> square	ANOVA sig.		
1	(Constant)	0.343	0.003	-0.352	.827
	PFDuration			0.850	.003
2	(Constant)	0.451	0.001	-2.131	0.228
	PFCOUNT			0.300	0.001
3	(Constant)	0.330	0.004	-0.257	0.874
	PTimeVisit			0.794	0.004

Dependent variable: picture beauty

## Discussion

This research has tested an innovative eye-tracking method to measure the relative perceived beauty of images taken of underwater scenes from the Great Barrier Reef. In this study, beautiful pictures which are pleasant to the eyes will attract more attention than ugly pictures (H1 confirmed). On average, participants spend about 8 seconds viewing a beautiful picture in comparison for 5.4 seconds per ugly picture. Our research outcome supports for aspects of Leder et al.'s (2004) five-stage model of aesthetic appreciation and aesthetic judgment. The first three stages involve bottom-up perceptual processes to recognize and analyse pictorial features (i.e. perceptual analyses), its prototypicality and familiarity (i.e. implicit memory integration) and its style and content (i.e. explicit classification). Normally, these automatic processing stages could occur rapidly and automatically in the first 3 seconds of looking at a picture (Locher et al., 2007). Hence, people are able to make a rapid evaluation of a picture's content and aesthetic appeal at first glance (after the first 3 seconds) (Rasche & Koch, 2002). The fourth and fifth stages of aesthetic experience involving self-related interpretation and aesthetic appreciation are more deliberate (i.e. top-down) processes. Viewers can decide to stop or spend more time looking at a picture depending on its aesthetic pleasure (Locher et al., 2007). Our research outcome confirms the importance of using beautiful and pleasant images in tourism marketing to capture and retain tourist attention (Wang & Sparks, 2016). Because tourists are exposed to thousands of visual stimuli per day, audience attention to a tourism marketing message is a key success factor (Scott et al., 2017).

Moreover, it was found that eye-tracking measures (i.e. fixation count, fixation duration and total time visit) can be used as reliable indicators of perceived beauty of natural scenes (H2 confirmed). Aesthetic value is an important criterion of natural attractions like the Great Barrier Reef and its World Heritage listing. To date, there is no systematic and consistent methodology on how to assess the 'natural beauty or aesthetic value' (as articulated as part of Criterion vii in the statements of Outstanding Universal Value) within the World Heritage Convention (Mitchell, Migon, Denyer, & Leitão, 2013). This study contributes to the development of such a methodology. The eye-tracking method suggests a means for objective measurement of the relative beauty of natural images and potentially for monitoring the aesthetics of environments such as underwater coral reefs. Use of this method may allow the tracking of beauty over time and hence contribute to monitoring the sustainability of world heritage areas (de Fauconberg, Berthon, & Berthon, 2018). Based on our research findings, eye-tracking technology could also be applied by tourism marketers in market research to compare and identify the most beautiful and attractive images of a natural attraction for tourism promotion purpose.

The results of this research provide further evidence of the usefulness of eye-tracking methods specifically and of cognitive psychology theory and methods generally in informing tourism research. Previous studies primarily applied retrospective self-reported measures of attention (Dowray, Swartz, Braxton, & Viera, 2013; Mackison, Wrieden, & Anderson, 2010; Verbeke & Ward, 2006) which are likely biased operationalization of identifying true attention (Bialkova & van Trijp, 2011). Hence, researchers have recently begun to apply eye-tracking methods to study the actual attention of tourists paid to tourism marketing stimuli, for example, images



for hotels and airline marketing (Babakhani, Ritchie, & Dolnicar, 2017; Wang, Tsai, & Tang, 2018). Eye-tracking can be beneficial in investigating many further topics including evaluation of sponsorship (Breuer & Rumpf, 2012), advertising effectiveness (Scott et al., 2016) and wayfinding (Xia, Arrowsmith, Jackson, & Cartwright, 2008). Mobile eye-tracking technology is also available for future research to track individual eye movements at real-life tourism attractions such as a national park or art exhibition.

Moreover, we highly recommend further use of other advanced research technologies such as heart rate, skin conductance, EEG in advancing tourism research (Li, Scott, & Walters, 2015). These technologies are nowadays available at reasonable costs and have great potential to reduce research bias due to memory-based measures. Combining these research tools to examine the nature and relationships between tourist attention (eye-tracking), emotion (heart rate or skin conductance), involvement and information processing (EEG) is very promising in moving the tourist behaviour field forward.

This research is an initial study only and has several limitations. First, only one item was used to measure respondents self-reported beauty ranking, and it may also be useful to use other scales such as visual appeal (Mathwick, Malhotra, & Rigdon, 2001). Further research is needed to develop this method and compare its results with the expert-based judgment of aesthetic value (Beza, 2010; Schirpke, Timmermann, Tappeiner, & Tasser, 2016) especially of coral reefs (Goldman, 1990; Johnston & Smith, 2014). Second, this study is limited in terms of the number of images used (21 photos). The method needs retesting using larger numbers of photos – perhaps 60 pictures or more. Third, picture elements were not investigated in this study. However, it was found that photos with brightly coloured coral, multiple fish species, clear water and iconic species such as turtles were found more attractive. Photos rated as less attractive typically showed man-made objects such as discarded cans or bottles or expanses of white coral, less clear water and less fish. Therefore, beauty factors such as the quality of images, including factors such as colour composition, saturation and brightness (Seresinhe, Preis, & Moat, 2017) and special research methods such as conjoint analysis may be useful to determine the contribution of image elements to aesthetic assessment.

Forth, only basic eye-tracking measures were employed in this study, but a variety of other eye-tracking metrics and techniques are available to measure attention such as gaze-entropy (Raptis et al., 2017) and scan-path length (Katsini et al., 2018). Hence, more sophisticated eye-tracking experiments should be set up in future studies. Fifth, only Australian participants were employed for this study. It would be useful to examine respondents from different cultural backgrounds (Asia vs Western) to determine if there are differences in their aesthetic perception. There is some evidence to suggest that there are differences in fixations on areas of interest in an image (Wang & Sparks, 2016) and variations in eye-movements during scene perception related to the culture of the subject (Chua, Boland, & Nisbett, 2005).

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