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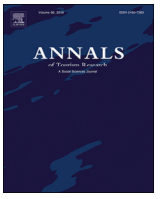

Research Article

A review of research into neuroscience in tourism: Launching the annals of tourism research curated collection on neuroscience in tourism

ShiNa Li [a,*], Robin Chark [b], Marcel Bastiaansen [c], Emma Wood [d]

[a] School of Tourism Management, Sun Yat-Sen University, Key Laboratory of Sustainable Tourism Smart Assessment Technology, Ministry of Culture and tourism, Tangjia Wan, Zhuhai 519082, China
[b] Faculty of Business Administration and Centre for Cognitive and Brain Sciences, University of Macau, China
[c] Academy for Leisure and Events, Breda University of Applied Sciences & Department of Cognitive Neuropsychology, School of Social and behavioural Sciences, Tilburg University, Netherlands
[d] The School of Events, Tourism and Hospitality Management, Leeds Beckett University, United Kingdom

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ABSTRACT

The growth of neuroscience studies within tourism has been relatively slow, with limited well-executed studies and little interdisciplinarity. The aim of this review is to stimulate the use of neuroscience within tourism research. It first discusses the synergies to be gained by combining neuroscience with social science, exploring the usefulness and suitability of using neuroscience within tourism. An evaluation of review articles that have critiqued individual applications of neuroscience in tourism is presented, followed by a comprehensive overview of neuroscience methods. We discuss the theoretical relevance of neuroscience and its potential themes for a tourism neuroscience research agenda. This discussion is based on a selective review of wider neuroscience of relevance to tourism, including affective neuroscience, neuromarketing, neuroeconomics and neuromanagement.

Introduction

The application of neuroscience to tourism research is attracting increasing attention (Lei, Chen, Wu, Zhang, & Lv, 2022; Li, Lyu, Chen, & Zhang, 2022; Li, Sung, Lin, & Mitas, 2022; Savin, Fleşeriu, & Batrancea, 2022). Neuroscience can be used within tourism research to better generate and test theories, generate more accurate measures, and guide the development of new hypotheses and assumptions (Waldman, Wang, Hannah, & Balthazard, 2017). Despite these advantages, the growth of neuroscience-based studies within the tourism field has been slow, with a lack of theoretically grounded studies and little interdisciplinarity. The aims of this curated collection of *Annals of Tourism Research* are to stimulate more and better research that applies neuroscience to tourism and to bring both theoretical and practical implications to the attention of tourism academics, tourism policymakers and the wider tourism industry.

Tourism scholarship, and social science more generally, has begun to embrace aspects of neuroscience (Lei et al., 2022; Ma, Hu, Pei, Ren, & Ge, 2014). However, the relationship between social science and tourism remains fractious and, in some ways, com-

* Corresponding author.
E-mail addresses: lishina@mail.sysu.edu.cn (S. Li), Bastiaansen4.M@buas.nl (M. Bastiaansen), E.Wood@leedsbeckett.ac.uk (E. Wood).

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petitive, with each arguing that their approach is worthier (Antonietti & Iannello, 2011). Recently, there have been examples of neuroscience and social science being combined but not well integrated (e.g., Hadinejad, Moyle, Kralj, & Scott, 2019; Wood & Kenyon, 2018). To add perceived credibility, a social science study may add some physiological measurements or a neuroscience study may add a more qualitative component, based on a 'bolted together' rather than 'working together' approach. There remains, therefore, great potential to strengthen this relationship and create truly integrated multidisciplinary studies of tourism phenomena. This review is a step on the path bringing social science and neuroscience closer together by setting out a truly interdisciplinary research agenda for tourism scholarship.

Both individual and review studies of neuroscience in tourism have focused on explaining and revealing advances in neuroscience methods; the theoretical relevance of such advances has been less discussed. Neuroscience can make significant methodological contributions to tourism research by capturing objective, subconscious and spontaneous emotional responses in real and continuous time. This is difficult to achieve using traditional self-report methods, such as surveys and interviews.

Tourism scholars may not be fully aware of the developments of neuroscience as most relevant studies are published in neuroscience journals. This curated collection of neuroscience in tourism aims to spotlight best practice in this growing field, explore the potential for contributing to tourism knowledge and act as a call for others to explore the possibilities of integrating neuroscience methods into their empirical studies. For these purposes, we first critically discuss the relationship between social science and neuroscience, and how neuroscience adds value to social science. Given that the majority of readers of Annals of Tourism Research may be unfamiliar with the methods and theories of neuroscience, we then evaluate review articles that have critiqued individual applications of neuroscience methods in the tourism field, thus taking a 'review of the reviews approach' to provide a full picture of the development of neuroscience in tourism, and provide a comprehensive overview of neuroscience methods with an explanation of their utility for tourism studies. Finally, we emphasise the theoretical relevance of various strands of neuroscience, including affective neuroscience, neuromarketing, neuroeconomics and neuromanagement, when setting up a research agenda.

Social science and neuroscience

Mistrust exists between neuroscience and social science based upon their fundamentally different perspectives on knowledge. Neuroscience is situated in an individualistic epistemology traditionally divorced from social environments, whereas social science, unsurprisingly, embraces social epistemology and the epistemic effects of social interactions and social systems (Goldman & O'Connor, 2021). Neuroscience tends to claim the higher ground, arguing that other approaches have little to add when "brain activity is the 'ground' of individual behaviour" and so, some would argue, neuroscience can exhibit true causal mechanisms (Legrenzi & Umiltà, 2009:262). It has been claimed, for example, that the methods employed in neuroscience can overcome the lack of validity and problems of social desirability bias associated with self-report measures (Li, Walters, Packer, & Scott, 2018; Scott, Green, & Fairley, 2016; Sop, 2021).

The basis for this argument is that the heuristic power of neuroscience and its rigour, precision and core focus can lead to the elimination of other sciences. That is, neuroscience is a unifying approach that can explain all phenomena. This leaves social science fighting for their place in the world, forced to justify what they can do that neuroscience cannot. 'Within this picture, social sciences … are challenged to defend the heuristic and explanatory power of the approach they adopt to investigate their subjects' (Antonietti & Iannello, 2011, p. 309). Take for example the argument that self-report is less valid than physiological measures of emotional arousal. In many situations, what is said is of greater interest than what is physically manifested. Word-of-mouth is one example, where the impact on others comes from what is said rather than what is felt (Chen, 2017; Cowley, 2014).

In arguing, therefore, for the greater application of neuroscience within tourism studies it is also important to recognise that this cannot be done in isolation. Neuroscience is not a 'golden key' to unlock perfect knowledge but an additional set of tools that can further enhance understanding. We argue, echoing Antonietti and Iannello (2011), for an integration of neuroscience with social science. Integration entails one explanation adding depth to the other rather than always offering different explanations for phenomena. Such integration would enable a holistic understanding of collective phenomena and their constituents (in terms of the behaviours of individuals and their reactions to externalities), the reasons for those behaviours in terms of mental processes and the underlying brain mechanisms behind the mental processes (Antonietti & Iannello, 2011; Parrinello, 2012). Within tourism, we are interested in collective phenomena, individual behaviours, mental processes and, albeit perhaps less so to date, brain processes. Each level has something to add to helping us understand the complexities of tourism, the tourist, and the toured.

Consider the case of 'water' and 'H_2O' being the same thing but described differently (Antonietti & Iannello, 2011). One can be considered analogous to mental processes and the other as analogous to brain functioning. However, water can be many things (therapeutic, aesthetic, thirst quenching, a medium on which to travel) and therefore, brain function ('H_2O') alone cannot fully describe these phenomena. To illustrate this further, Antonietti and Iannello (2011), p. 313) drew an important distinction between the study of physical realities and of the mind:

> In the scientific study of physical realities, it makes sense to move from appearance (e.g. 'water') to a 'deeper' reality ('H_2O'), whereas as far as the mind is concerned, it is not a question of going from appearance to a deeper reality, because the subjective appearance is the essence of the mind. There are no appearances beyond the emotions, the memories, the impressions. If I feel fear, the sensation of the fear is all I feel; it is a non-sense to say that the fear is actually a neural process.

Take for example, a study by Stadler, Jepson, and Wood (2018) of older women's experience of craft events. Measures of electrodermal activity showed peaks of emotion during the experiences, but the participants' explanations of those peaks when graphs of electrodermal activity were used as a stimulus for later discussion showed how they remembered feeling. The two phenomena were quite different, with how the participants remembered feeling potentially having a greater effect on their current attitudes and behaviour. A subjective description of the mental experience is therefore needed to understand observed brain patterns if we are to connect neural processes to the external world. It is not sufficient for social science to describe a personal experience and neuroscience to tell us what happens in parallel in the brain. At least two levels of description, the psychological and the neuroscientific, are needed to understand the complex world we live in.

The move from the individual to the social appears to be the barrier to interdisciplinarity but also the area in which interdisciplinarity would bring the greatest gains within tourism research. Social science in its broadest terms could work with neuroscience to consider the 'biosocial entanglement of human life' (Callard & Fitzgerald, 2015, p. 22). Stanca (2011) also discussed the need to bridge the gap between the different theoretical approaches and methodologies related to the study of the individual and the study of society, creating an interdisciplinary 'basis for more accurate models of decision making and a better understanding of social phenomena' (p. 253).

At the very least, tourism scholars should gain an appreciation of what neuroscience can add to the field. As Rusconi, Sedgmond, Bolgan, and Chambers (2016), p.261) rightly stated, 'it is useful and important for social scientists to acquire foundational concepts and become aware of the advantages and limitations of the most popular neuroscientific techniques. In this way they can reach a critical appreciation of the evidence'. However, despite these arguments for inclusion within the largely social science-based tourism field, little seems to have been achieved since Parrinello (2012), p. 40) argued that

> an adequate theoretical apparatus, informed by the current state of the art in neuroscience, is necessary when dealing with a multilayered and multifaceted phenomenon like tourism where, from a social and psychological point of view, the human being is positioned at the center.

Parrinello's (2012) discussion of neuroscience in tourism research suggested several areas where social science meets (or could meet) neuroscience: embodiment, qualia (consciousness), the extended mind and the ground-breaking discovery of mirror neurons. The tourist experience has been generally accepted and examined as embodied for over 10 years but few studies have used neuroscience methods to understand embodiment. Qualia, or higher-order consciousness, emphasises the phenomenological/qualitative aspects of tourism experiences, which cannot be understood by neuroscience alone.

The extended mind – the connection of the 'I' to the external world – creates many opportunities for interdisciplinarity in tourism, such as exploring technologies that 'extend the tourist mind', e.g., global positioning systems, augmented reality, and the metaverse. It seems then that neuroscience can no longer be ignored within tourism. If we have the means to look inside the tourist's brain to quantify the embodied experience, then we should do so (Parrinello, 2012). As discussed above, although neuroscience alone is not enough, when incorporated into a truly interdisciplinary approach, it can lead to great leaps in tourism research.

Neuroscience in tourism: a review of reviews

To discuss the potential of neuroscience in tourism research, it is first necessary to provide an overall picture of its current application in the field. This section takes 'a review the reviews' approach (Weed, 2009, p. 615), which does not simply replicate previous reviews but offers a more enlightening and systematic analysis. This approach helps to generate new interpretations and identify research gaps and prospects.

The review process involved two rounds of article selection. First, the keywords neuroscience, electroencephalography, electrodermal activity, skin conductance, functional magnetic resonance imaging, eye tracking, facial expression, heart rate, tourism, and hospitality were used to search the EBSCO database and Google Scholar for articles published in peer-reviewed journals. Second, articles identified in the first round were selected according to the following criteria:

- Articles that reviewed research on the application of neuroscience in tourism but did not collect or analyse any neuroscience data.
- Articles that evaluated various neuroscientific methods but did not collect or analyse any neuroscience data.

Based on these criteria, nine review articles were identified that shed light on the potential for future studies in this area. Table 1 summarises six main features of these review articles, including publication information (authors and publication year), journal name, neuroscientific method(s), number of articles retrieved, relevant theories and concepts, and main suggestions for further research.

Most of the review articles were published in the past five years, with five published in 2021 and 2022, and only one published earlier, in 2014. The earlier paper reviewed the use of neuroscience outside of tourism to inform its potential application to tourism (Li, Scott, & Walters, 2014). This suggests that research on neuroscience in tourism is a relatively recent trend but one that is gaining in popularity.

Table 1 indicates that the earliest and most frequently used neuroscience measure is eye tracking, with the first review article on this topic published in 2014. Savin et al. (2022) retrieved 70 studies that used eye tracking in tourism research. Electrodermal activity is the second most common measure, with 25 relevant articles reviewed by Li, Sung, et al. (2022). Electroencephalography

Table 1
Review articles on neuroscience research in tourism.

Authors	Journal	Method(s)	No. of articles	Theories and concepts	Some main conclusions of the review articles
Li et al. (2014)	Current Issues in Tourism	Electrodermal activity, Heart rate, Facial expression, Eye tracking, Vascular	12[a] 6[a] 8[a] 7[a] 2[a]	Emotion	Recommended that researchers combine different psychophysiological measures Recommended that researchers combine self-report and psychological measures
Bastiaansen et al. (2019)	International Journal of Contemporary Hospitality Management	Facial expression, skin conductance response, heart rate, electroencephalography, event-related potential, functional magnetic resonance imaging	N/A	Emotion, Experience	Complementing facial coding, physiology and electroencephalography with traditional methods is better for measuring emotion The above neuroscience methods can evaluate the ebb and flow of emotions
Scott, Zhang, Le, and Moyle (2019)	Current Issues in Tourism	Eye tracking	16	Attention	Main areas for the use of eye tracking in tourism: choice analysis, distribution channel conversion analysis, facility design analysis, employee development, tourist attentional processing, tourists' interaction with virtual products Scene viewing and visitor aesthetic evaluation using mobile eye tracking
Atabay and Güzeller (2021)	Tourism: An International Interdisciplinary Journal	Eye tracking	64	/	Did not provide many suggestions for further research using eye tracking
Lei et al. (2022)	Journal of Hospitality & Tourism Research	Electroencephalography, Functional magnetic resonance imaging, Skin conductance response	6 2 8	Emotion	Decision making, emotions and cognition are three topics suitable for neurophysiological application in tourism.
Savin et al. (2022)	Journal of Vacation Marketing	Eye tracking	70	/	Topics of interest: attention level, consumer behaviour, perception and memory in relation to socio-demographic variables Recommended using dynamic stimuli
Li, Sung, et al. (2022)	Annals of Tourism Research	Electrodermal activity	25	Emotion	Recommended collecting larger samples, particularly in field research; reporting all relevant information about electrodermal activity; and distinguishing skin conductance response and skin conductance level
Li, Lyu, et al. (2022)	Journal of Hospitality & Tourism Research	Electroencephalography	1 33[b]	The behavioural inhibition/activation system, emotion, attention, empathy, memory, preferences, self-control	Proposed various themes to which electroencephalography can be applied in tourism and hospitality. Electroencephalography can be used to examine the emotion, memory, and empathy of tourists.
Al-Nafjan, Aldayel, and Kharrat (2023)	Brain Sciences	Eye tracking, Electroencephalography, Galvanic skin response, Facial-action-coding, Combination of various modalities	21 6 2 1 9	Affect, attention, cognitive load	Suggested to select the most powerful stimuli, employ a triangulation method, build interdisciplinary collaborations, facilitate building artificial intelligence models, use machine learning models

[a] Indicates that these articles are not in the tourism field but address general marketing, advertising, media, psychology or neuroscience topics relevant to emotion.
[b] Indicates that these articles are in the general business and management field.

and eye tracking are the most commonly used neuroscience methods in marketing research (Alvino, Pavone, Abhishta, & Robben, 2020). There is also a growing trend in the use of electroencephalography, with several new applications featuring in this curated collection. Although eye tracking and electrodermal activity are the most used techniques, they have been misused in some applications. For example, Li, Sung, et al. (2022) pointed out that some studies have failed to distinguish between skin conductance response and skin conductance level, leading to errors in the choice of electrodermal activity metrics. Tourism researchers have also started to use electroencephalography and functional magnetic resonance imaging (Lei et al., 2022).

Traditional methods require respondents to answer closed or open-ended questions to reveal their feelings, known as a 'self-report' approach (Li et al., 2014). All of the review articles critically compared self-report and neuroscientific approaches and pointed out how neuroscience methods can overcome the limitations of self-report methods. The retrieved review articles reported four main ways in which neuroscience methods can overcome some of the limitations of self-report methods: they can reduce cognitive bias and social desirability influence, capture unprompted and subconscious/unconscious emotion, and continuously measure emotion in real time. It is worth emphasising that neuroscience complements rather than replaces the traditional

self-report approach. As with all other methods, each neuroscience method also has limitations. For example, electroencephalography and electrodermal activity cannot capture valence. Although neuroscience methods can overcome some of the limitations of self-report approaches, on their own they often lack explanatory power. That is, they show us what happens but not why it happens (Paris, 2017). To increase the reliability, validity and accuracy of research on tourists' emotional responses, it is recommended that multiple psychophysiological methods and self-report methods are combined (Lei et al., 2022; Li et al., 2014).

Interestingly, all of the review articles focused on methods, with few discussing the theories or concepts that can be applied to neuroscience in tourism or the potential theoretical contributions. After reviewing 33 studies that used electroencephalography in the business and management field, Li, Lyu, et al. (2022) identified possible theories and concepts for which electroencephalography may be a useful tool in tourism research, including behavioural inhibition/activation systems, emotion, attention, empathy, memory theories, preferences and self-control.

Emotion is one of the most discussed concepts in the reviewed literature. Emotion is the most direct and pragmatic angle for the combination of neuroscience and tourism for two main reasons. First, emotion has commonly been used to evaluate memorable tourism experiences, which largely influence experiential outcomes such as satisfaction, attitude and behavioural intention (Bastiaansen et al., 2019); second, neuroscience methods such as skin conductance responses and electroencephalography are useful in evaluating emotional arousal (Li et al., 2014; Li, Lyu, et al., 2022). Moreover, tourism advertising, tourism marketing and tourist experience are the most common areas in which neuroscience methods have been applied (Li, Lyu, et al., 2022). This leaves clear gaps in areas such as tourism management, tourism operations and tourism economics, all of which could be investigated using neuroscience methods.

Overview of neuroscience methods

Human neuroscience involves measuring physiological activity from the human body that is a direct reflection of, or under the immediate control of, the human nervous system. Well-established neuroscience methods such as electroencephalography and functional magnetic resonance imaging reflect the activity of the central nervous system (the brain, brain stem and spinal cord). In contrast, measures such as heart rate and heart rate variability, skin conductance responses, facial expressions, eye tracking and pupil dilation reflect the activity of the peripheral nervous system (the afferent nerve cells that pass sensory information to the brain, and the efferent nerve cells that drive our muscles, hormone glands and other bodily functions).

Below, we briefly review these research tools, distinguishing between peripheral physiological measures and measures of the central nervous system. For a comprehensive review of neuroscience methods and their application to a wide range of cognitive and affective phenomena, see Poeppel, Mangun, and Gazzaniga (2020).

Peripheral physiological measures

Skin conductance responses

'Electrodermal activity' is a general term that refers to the electrical properties of the skin, which are known to change over time, on a timescale of seconds. Changes in electrodermal activity stem from changes in sweat excretion from the sweat glands, which are under the direct influence of the hypothalamus and the surrounding limbic system, brain areas that are primarily involved with the processing of arousal and emotions. Relatively rapid changes in electrical skin conductance, so-called 'skin conductance responses', when reliably related to the events that elicit them, are therefore a reliable index of emotional arousal (Boucsein, 2012), at least when properly analysed (Bastiaansen, Oosterholt, Mitas, Han, & Lub, 2022). As discussed in the previous section, an increasing number of tourism studies have recorded skin conductance responses, for example, when studying tourists' emotional highs on a guided tour (Mitas et al., 2022) or emotional responses to tourism marketing materials (Li et al., 2018).

Heart rate and heart rate variability

Just like electrodermal activity, heart rate, i.e., the frequency at which the heart beats, is under the influence of the autonomous nervous system (the part of the nervous system that is not under volitional control). In contrast with skin conductance responses, which are under the sole control of the sympathetic nervous system (activating 'fight, flight or freeze' responses; Boucsein, 2012), heart rate is also under the influence of the parasympathetic nervous system (de-activating, rest-and digest, feed-and-breed). Typically, activity in the sympathetic nervous system increases heart rate, while activity in the parasympathetic system decreases heart rate. In normally functioning individuals, the sympathetic and parasympathetic nervous systems interact antagonistically to produce varying degrees of physiological arousal (Pham, Lau, Chen, & Makowski, 2021).

In addition to being an index of physical arousal, heart rate has been consistently found to be related to increased emotional arousal, at least in carefully controlled laboratory settings (for a review, see Kreibig, 2010). Another measure of interest is variability in heart rate over time. Heart rate variability has been robustly shown to be related to cognitive and affective phenomena (Laborde, Mosley, & Thayer, 2017). It can also be used to signal episodes of increased emotional arousal. For example, heart rate variability is higher during emotionally arousing episodes than during non-arousing episodes (Berntson et al., 1997). Only a few tourism studies have employed heart rate (variability) as a measure. One study addressed differences in emotional arousal between rural and urban tourism environments (Joung et al., 2020). Another addressed the differences in emotional response between Dutch and German visitors at a World War II museum (Mitas, Cuenen, Bastiaansen, Chick, & van den Dungen, 2020).

Facial expressions

The facial expressions of humans (and most animals) convey a wealth of information about how they think and feel. Facial expressions have therefore been extensively studied in social psychology, and in the psychology and neuroscience of emotions (Ekman, 1993; Krumhuber, Kappas, & Manstead, 2013).

Facial expressions result from the concerted activity of groups of facial muscles. This provides two options for quantifying and measuring them. One is by attaching electrodes to parts of the face that overlie the relevant muscles. This so-called 'facial electromyography' has been found to be a reliable index of the experience of different emotions (Dimberg, 1990). Another approach to quantifying facial expressions is to carefully define and categorise them on the basis of pictures or video of faces, through an elaborate and well-established system of facial action coding developed by Paul Ekman, a pioneer in emotion research (Ekman, Friesen, & Hager, 1978). The facial action coding system defines a number of facial muscle groups, called action units, which through concerted action express a particular emotion.

The measurement of facial expressions to detect which categories of emotions people are experiencing, either through facial electromyography or through video-based facial action coding, has been used extensively in emotion research (see, e.g., Adolphs, 2002). Traditionally, facial coding was a time-consuming task that required detailed knowledge of the facial muscles and the underlying system of action units. Today, software is available that can automatically detect action units and distil facial action coding system patterns from pictures and video, making it a relatively easy to use measure for tourism researchers without expertise in this area (Lewinski, Den Uyl, & Butler, 2014). Both software-based facial action coding (Scuttari, 2021) and facial electromyography (Li et al., 2018; Li, Lyu, et al., 2022) have been used to assess responses to tourism advertising.

Eye tracking and pupil dilation

The proverb 'the eyes are windows to the soul' suggests that the eyes indicate how one feels or what one is thinking. To some extent, this is true. At least two peripheral physiological measures are based on this old proverb. One is eye tracking, which involves continuously measuring the point on which people are focusing their gaze. Eye tracking involves monitoring fixations (when the gaze is directed at a specific point in space for a given time period) and saccades (periods in between fixations when the gaze is shifting from one point to the next; Hutton, 2019). Eye tracking has been extensively used in a wide range of domains, from language comprehension to visual perception, from marketing to urban design, and from behavioural economics to spatial attention (Klein & Ettinger, 2019).

Pupil dilation has been used extensively since the 1970s as an index for a wide range of cognitive and affective phenomena, including cognitive load (van der Wel & van Steenbergen, 2018), memory storage and retrieval (Goldinger & Papesh, 2012), emotions (Bradley, Miccoli, Escrig, & Lang, 2008), and pain (for a review, see Peinkhofer, Knudsen, Moretti, & Kondziella, 2019). Most modern eye tracking systems, especially video-based ones, can also measure pupil dilation, such that when recording eye tracking, pupil dilation measures can be derived from the eye tracking data (Hutton, 2019). Eye tracking has been used relatively often in tourism research as a tool to study visual attention in advertising, the processing of photographs of tourism activities, perceptions of landscape images, and website useability (cf. Scott et al., 2019). We suggest other possibilities within tourism include the focus of tourists' attention during a cultural performance and what catches their eye when first arriving in a hotel room.

Measuring cognitive and affective processes from the central nervous system

Functional magnetic resonance imaging

Functional magnetic resonance imaging is a neuroimaging technique that was developed in the 1990s and which has had a huge impact on the field of cognitive and affective neuroscience. It allows for the creation of three-dimensional images of the living human brain and visualisation of brain areas that are active at a given moment in time (Gauthier & Fan, 2019). Functional magnetic resonance imaging maps provide a view of brain activity with a high spatial resolution (up to 1 mm^3, depending on the type of scanner and the specific scanning protocol used). A downside to functional magnetic resonance imaging is its poor temporal resolution. The technique is largely blind to the timing of brain processes.

Three decades' worth of very active functional magnetic resonance imaging research (a Google Scholar search with the search term 'functional magnetic resonance imaging' yields more than 1 million hits) has uncovered a wealth of scientific knowledge. With unprecedented detail the research findings document, for example, which brain areas are involved in specific cognitive functions (e.g., Logothetis, 2008) and which are involved in processing emotions (Phan, Wager, Taylor, & Liberzon, 2002). Previous applications of functional magnetic resonance imaging in tourism include studying the impact of destination images on tourist decision making (Al-Kwifi, 2015) and the emotional responsiveness of frontline hospitality employees (Choi, Kelley, Walden, McCool, & O'Boyle, 2022).

Electroencephalography

Electroencephalography involves recording the electrical activity of the brain. It is predominantly sensitive to the activity (more specifically, the postsynaptic potentials) of the large pyramidal neurons in the neocortex, the outer layers of the brain (Nunez, 2000). Electroencephalography is a prominent research tool for cognitive psychologists (see, e.g., Sutter & Kaplan, 2017). Electroencephalographic equipment is affordable, data collection is relatively easy, and widely available and dedicated data analysis software allows collected data to be analysed with much greater ease than before. Unlike functional magnetic resonance imaging, electroencephalography is a direct, rather than an indirect, reflection of neural activity, and it thus has an excellent time resolution, in the order of milliseconds. However, electroencephalography mainly reflects the activity of the neocortex. It

is mostly blind to the activity of subcortical structures, in contrast with functional magnetic resonance imaging's clear three-dimensional view of the brain in action.

Electroencephalography is generated by the superposition of many different neural processes, most of which may not be of interest to the researcher in business studies (e.g., processes related to maintaining body posture, regulating blood pressure, and basic sensory processing). To isolate neural processes of interest from uninteresting ones, electroencephalography studies typically consist of very short tasks (e.g., viewing and evaluating visual stimuli, performing simple cognitive tasks) that are repeated at least 20 or 30 times. The electroencephalography time segments that correspond to these short tasks are then averaged, the justified assumption being that the neural processes related to the task are highly similar (i.e., stationary) across repetitions of the task, whereas activity related to all other neural processes is non-stationary and averages out. The resulting averaged electroencephalography segments are termed event-related potentials (see Luck, 2014 for background and technical description). Event-related potentials consist of electrical peaks and troughs that can be consistently identified, which are referred to as event-related potential components. In the last four decades, hundreds of thousands of event-related potential studies have established in great detail how different event-related potential components are related to a wide range of cognitive and affective processes (see Luck & Kappenman, 2011 for a comprehensive overview).

In addition to the event-related potential approach, an alternative approach has been to identify oscillations in the electroencephalograph within different frequency bands (referred to as theta, alpha, beta, and gamma oscillations), and to relate changes in the amplitude and phase of these oscillations to cognitive and affective phenomena, such as top-down visual perception, language comprehension, attention, and working memory maintenance (e.g., Bastiaansen, Mazaheri, & Jensen, 2012; Siegel, Donner, & Engel, 2012; Varela, Lachaux, Rodriguez, & Martinerie, 2001). In tourism, electroencephalography has been used to study how destination marketing affects affective destination image (Bastiaansen et al., 2018; Bastiaansen et al., 2022) and words that describe destination personality (Wang, Li, Li, Li, & Lin, 2022).

Using neuroscience in tourism research

In the past decade, neuroscience research methods have gradually been introduced into the field of tourism research because they have several advantages over more traditional research techniques used in tourism research (such as surveys or interviews). An obvious advantage of neuroscience research methods is that they provide objective measures that are not under volitional control. This contrasts with traditional methods, which rely on self-report and are therefore subject to social desirability bias and other negative consequences of self-report measures.

Another advantage of neuroscience methods is that they sample (neuro)physiological measures in real time, whereas survey or interview techniques typically involve measurement after an event has happened or an experience has taken place. Moreover, the time series data yielded by neuroscientific measurements allow researchers to study how responses evolve over time, with subsecond precision. This is of particular interest when examining, for example, emotional responses in a tourism context, as it allows the waxing and waning of emotions to be tracked in real time as people experience tourism.

Clearly, these advantages make neuroscience techniques especially suitable for measuring concepts that are of interest to tourism scholars but are not easily measured with self-report-based methods. Such concepts include, but are not limited to, un- or subconscious processes, implicit associations, bias, stress and emotions. Also, studies that specifically focus on temporal dynamics, such as those addressing experiences, may benefit from the use of neuroscience techniques. In summary, tourism research has much to gain from using neuroscience techniques, especially when they are used in conjunction with traditional tourism research methods such that the results obtained from different methods can be combined and triangulated.

Lab studies vs field studies

Neuroscientific research traditionally takes place in laboratories, in which very sensitive equipment is used to record measures from the human body under perfectly controlled conditions. This is at odds with the aims of most tourism research, which attempts to measure tourists' behaviour, thoughts, and feelings in real-life settings. The emergence of techniques such as virtual, augmented, and mixed reality allow the tourism experience to be brought into the lab to some extent. However, in an ideal study, tourism research takes place where tourism happens, in the field. The question therefore is to what extent neuroscience techniques are suitable for use outside of the laboratory. Let us first consider peripheral physiological measures.

Electrodermal activity is easily collected, both in a laboratory setting and using wearable devices for measurement in real-life settings. In a laboratory setting, electrodes are typically attached to two fingertips, a small and unnoticeable current is passed through the electrodes, and the electrical resistance (the inverse of electrical conductance) is measured. In field settings, electrodes are typically integrated into wristbands, after which electrodermal activity is measured from the wrist, and/or short electrical wires connect the wristband to electrodes attached to the palm of the hand. Benchmark studies (e.g., Sagl et al., 2019) have shown that data from such wearable devices are comparable in quality, reliability and validity to those from high-end laboratory equipment. Heart rate is measured as the electrical activity produced by the heart (the electrocardiogram). However, in most wearable devices heart rate is estimated based on recording a photoplethysmogram a non-invasive technology that uses a light source and a photodetector on the surface of the skin to measure the volumetric variations of blood circulation. Although photoplethysmogram measurements yield a fairly accurate estimate of heart rate, benchmarking suggests that the electrocardiogram is the more accurate of the two methods (Sagl et al., 2019).

For studying facial expressions, recording facial electromyography is the method of choice in lab settings, as it is very sensitive and detects facial muscle activity even when it is not visible to the naked eye. In contrast, in field studies, recording video is an

easy way of collecting data that can be subsequently analysed with commercially available software that extracts and categorises facial expressions from video. For eye tracking and pupil dilation, head-mounted or desk-mounted equipment was traditionally only suited to lab studies, but recently wearable glasses have become available that allow for naturalistic recording conditions in the field.

The main challenge for tourism studies that aim to use peripheral physiological measures in real-life settings, therefore, is not the quality of the recorded data. Rather, it lies in ensuring that the various measures, recorded with subsecond precision are reliably, validly and consistently related to the factors in these real-life settings that are of interest to the researcher. This is easier said than done, as it requires developing systematic procedures and protocols for accurately manipulating, monitoring, identifying, timing, storing and reporting the events of interest that occur in a noisy, multi-stimulus, real-life environment. Good neurotourism field research should therefore very carefully consider the conditions under which field studies are an appropriate choice.

For measures of the central nervous system, the picture is different. To date, only a handful of electroencephalography and functional magnetic resonance imaging studies have been performed in a tourism context (for a review, see Lei et al., 2022). For functional magnetic resonance imaging, it is easy to see how drawbacks of the methodology prohibit the widespread use of the technique in a tourism context. This type of research requires very expensive equipment (a magnetic resonance scanner costs several million US dollars), and operating the scanner and analysing imaging data requires very specific expertise. Also, functional magnetic resonance imaging research is solely lab-based and imposes severe restrictions on participant mobility (participants must lie very still on their backs, without moving their heads) and on stimulus presentation (e.g., visual stimuli have to be presented as projections on a mirror just above the participant's head). These restrictions may limit the application of functional magnetic resonance imaging measurements in tourism research.

For electroencephalography, the situation is different. Although only a small number of electroencephalography studies to date have addressed topics relevant to tourism scholars (for a review, see Lei et al., 2022; Li, Lyu, et al., 2022), the combination of affordability and ease of use, and the potential for objectively measuring the cognitive and affective processes that are important for a cognitive–psychological perspective on tourism research, may constitute more favourable conditions for electroencephalography studies in tourism, at least in lab settings. In particular, the recent development of fully electroencephalography-compatible virtual and augmented reality devices leads us to believe that electroencephalography is a promising research tool for tourism scholars that has the potential to make a relevant contribution to tourism research in the years to come.

Despite the wide availability of mobile and wearable electroencephalography systems, we are sceptical of the use of electroencephalographic recordings outside of the laboratory. For one, the electroencephalogram is a very small electrical signal (measured in microvolts, or millionths of volts). It is therefore very prone to measurement artefacts produced by movement and by the electrical activity of muscles and eyes, which are typically larger by a factor of 10–100 than the electroencephalogram proper.

Beyond issues related to recording and artefacts, electroencephalography is a very noisy signal, consisting of the superposition of many different brain processes that occur in parallel. Careful experimental control and an appropriate data analysis strategy are required to isolate those brain processes that are of interest to the researcher from the others. This is at odds with a typical real-world tourism environment, in which there is very little control. Therefore, performing electroencephalography with wearable equipment in real-life environments entails attempting to understand how a very noisy signal relates to a very noisy environment. In our opinion this may be ill-advised.

Beyond methods: neuroscience's contribution to theory formation in tourism

This section considers broader areas in which neuroscience is likely to have a significant impact on theoretical development in the tourism field. Key examples from non-tourism fields are discussed and suggestions are made to illustrate how these examples might be extended to aspects of tourism research. Four particular areas – affective neuroscience, neuromarketing, neuroeconomics and neuroscience in management – are identified and discussed.

Affective neuroscience in tourism

Affective neuroscience is the branch of neuroscience that studies the neural basis of the affective system – the collection of emotions and moods that colour our lives. Moods are relatively understudied, both in psychology and in affective neuroscience. Most research has been devoted to understanding how emotions influence perception, cognition, decision making, and other processes. This is not surprising, as emotions are a crucial ingredient of human experience (Bastiaansen et al., 2019). They drive behaviour and influence social relations, memory formation, decision making and quality of life.

Emotions play a crucial role in tourism, as in other aspects of life. They inform travel decision making (Lerner, Li, Valdesolo, & Kassam, 2015), shape the tourist experience (Bastiaansen et al., 2019), partly determine the image that people have of destinations (Kim & Yoon, 2003; San Martín & Del Bosque, 2008), and play an important role in the relationship between tourists and local residents (Woosnam, Stylidis, & Ivkov, 2020). This brief review of affective neuroscience therefore focuses on emotions.

Different theories have been developed on the nature of emotions and the neural basis of emotions. Broadly, three classes of theory exist. One view posits that there exists a limited set of discrete, basic emotions, each with their own behavioural, neural, and physiological response pattern (Hamann, 2012). An important proponent of this view was Paul Ekman, who developed a theory of basic emotions consisting of happiness, sadness, disgust, fear, anger and surprise (Ekman, 1992). Importantly, basic emotions are assumed to be universal and innate (Ekman & Cordaro, 2011).

Dimensional models state that emotions are best expressed as a combination of two or three independent bipolar dimensions. The most widely adopted of these is the circumplex model of affect (Russell, 1980), according to which all emotional experiences can be placed on a circular map consisting of two independent bipolar dimensions called valence and arousal. Other models additionally posit a third dimension, dominance (Mehrabian, 1996).

Constructivist models suggest two distinct stages in the formation of an emotion. According to this view, emotions result from physiological responses such as arousal (Schachter & Singer, 1962) or core affect (Russell, 2003), followed by some form of appraisal of those responses. A more recent constructivist view is the theory of constructed emotion (Barrett, 2017a, 2017b; Barrett & Russell, 2014). According to this view, emotions are concepts constructed by the brain. These concepts are neural representations that are learned, shaped by culture and past experiences, and which predict sensory input. Feldman-Barretts theory of constructed emotions does not deny that discrete emotions exist. Instead, it claims that emotions are psychological constructs that are formed through interoception and categorisation (Barrett, 2017b). Two interoceptive signals are the consciously accessible, always present, bipolar dimensional mechanisms of valence and arousal, jointly called 'core affect' (Russell & Barrett, 1999).

The theory of constructed emotions considers valence and arousal to be the basic building blocks of emotions (Barrett, 2006). The theory therefore unites the dimensional view of emotions with basic emotion theory. Unlike basic emotion theory, however, the theory of constructed emotions considers discrete emotions to be learned and culturally dependent, which is clearly supported by empirical evidence (Lutz, 1988; Markus & Kitayama, 1991; Russell, 1994; Wierzbicka, 1986).

In advancing our theoretical understanding of the nature of emotions, neuroscience research methods are particularly useful. Our understanding of brain organisation, and empirical findings relating to brain anatomy and brain activation patterns in emotion elicitation paradigms (Siedlecka & Denson, 2019), can effectively inform and constrain theoretical views on emotion (see, e.g., Smith & Lane, 2015; Barrett, 2017a), although the theoretical debates are ongoing (e.g., Siegel et al., 2018) and sometimes ardently so (see Crivelli & Fridlund, 2019; Keltner, Tracy, Sauter, & Cowen, 2019). Neuroscience has certainly proved its worth as an independent source of information feeding into theories of emotion.

Affective neuroscience applied: measures of emotion of interest to tourism researchers

As has been demonstrated, the toolbox of the neuroscience-inspired tourism researcher is diverse, and different tools provide different perspectives on the emotions that play a role in tourism contexts. In Table 2 we summarise how the neuroscientific techniques discussed in the previous section translate into measures of emotion. Table 2 shows that neuroscience methods typically do not distinguish between different emotion categories. Rather, they predominantly index emotional arousal and/or emotional valence, with one exception – the analysis of facial expressions (see Barrett, Adolphs, Marsella, Martinez, & Pollak, 2019). Therefore, the overall pattern of empirical findings in affective neuroscience favours theoretical positions that do not posit the existence of basic emotions, that is, dimensional and constructivist theories (see Lindquist, Wager, Kober, Bliss-Moreau, & Barrett, 2012), although the dispute is unsettled (e.g., Phan et al., 2002). However, stepping aside from the theoretical debate, we believe that the overview presented in Table 2 provides tourism researchers with a methodologically diverse and innovative toolbox for studying emotions in tourism.

Table 2
Overview of neuroscientific measures of emotions.

Site of physiological activity	Measure of interest	Dimension of emotion measured	Key references
Skin (electrodermal activity)	Skin conductance responses	Emotional arousal	Boucsein, 2012; Dawson, Schell, & Filion, 2007
Heart	Heart rate, heart rate variability	Emotional arousal Emotion regulation Emotional valence?[a]	Kreibig, 2010; Laborde et al., 2017
Face (expression)	Facial electromyography	Discrete emotions	Adolphs, 2002; Dimberg, 1990
	Facial action coding, video-based	Discrete emotions	Ekman et al., 1978; Lewinski et al., 2014
Eyes	Eye tracking (fixations, saccades)	Emotional arousal, Salience	Hutton, 2019 Lim, Mountstephens, & Teo, 2020
	Pupil dilation	Emotional arousal	Bradley et al., 2008 Peinkhofer et al., 2019
Brain (functional magnetic resonance imaging)	Blood oxygenation level dependent response	Emotional valence Emotional arousal Discrete emotions	Knutson, Katovich, & Suri, 2014 Phan et al., 2002
Brain (electroencephalography)	Event-related potentials	Emotional arousal Emotional valence?[a]	Olofsson, Nordin, Sequeira, & Polich, 2008 Hajcak, Weinberg, MacNamara, & Foti, 2012
	Oscillations (theta, alpha, beta, gamma)	Emotional salience, Emotional valence?[a]	Güntekin & Başar, 2014 Siegel et al., 2012

[a] Individual empirical studies have sometimes reported a sensitivity to emotional valence (differentiating between positive and negative valence), but the robustness of these findings across studies is limited, and it remains disputed whether the measure in question can discriminate between positive and negative valence.

Suggestions for an affective neuroscience-inspired tourism research agenda

With the toolkit presented in Table 2 in mind, we now briefly address which areas in tourism research might benefit from such a toolkit. Clearly, emotions play a role in a wide variety of phenomena that are of interest for tourism scholars (e.g., Pearce, 2020; Volo, 2021). In this section we point to a few possible avenues for future research, without professing to be comprehensive or to propose a balanced research agenda.

Destination choice is thought to be at least partially driven by emotions (Pestana, Parreira, & Moutinho, 2020). Measuring those emotions while study participants are pondering the pros and cons of different destinations could further unravel to what extent and under what conditions emotions drive destination choice. Related to this, the construct of destination image has been shown to consist of a cognitive and an affective component (San Martín & Del Bosque, 2008). Affective neuroscience measures may help further determine the relative contributions of these two components to overall destination image.

Crowding is also an area in which affective neuroscience may inform tourism. Tourism destinations increasingly suffer from crowding, which reduces their attractiveness both to tourists and to local residents (Neuts & Nijkamp, 2012). However, perceptions of crowding may differ between situations, time of day, and purpose, and are also likely to differ greatly between tourists and residents. Emotions, and the level of emotional engagement with a particular destination are likely to play an important role in crowding perceptions (Xiao, Gao, Lu, Li, & Zhang, 2023). Developing continuous measures of perceived crowding, rooted in affective neuroscience, may provide a very helpful set of tools to better understand the psychological dynamics behind crowding perceptions. Another area where measures of emotion are crucial to tourism is neuromarketing, which is discussed in detail in the following section.

Neuromarketing in tourism

There is much that tourism scholars can learn from the growing application of neuroscience to neighbouring fields. For instance, combining neuroscience with consumer psychology has shown great promise in the emerging area of neuromarketing (Plassmann, Ramsøy, & Milosavljevic, 2012). The use of electroencephalograms to study consumer behaviour has a long history (e.g., Weinstein, Weinstein, & Drozdenko, 1984). The last two decades have seen the significant and ongoing development of this approach as a result of advances in neuroscience and the increased availability of magnetic resonance imaging to researchers (Shiv et al., 2005). This interdisciplinary approach enables a transformation of consumer behaviour research by incorporating insights from cognitive neuroscience (Hsu, 2017). The premise is that consumer behaviour results from psychological processes that are embodied physiologically in our brains (Chark, 2018). The ability to measure brain activity thus allows direct observation of underlying psychological processes and can answer research questions that may not have been fully answered in the past. This neuroscientific approach in consumer research suggests possible applications of neuroscientific tools in tourism research.

There is debate about whether this approach is a methodological advancement that results in theoretical contributions to consumer research or simply a branch of neuroscience borrowing the consumer perspective to study human behaviour (Plassmann, Venkatraman, Huettel, & Yoon, 2015). One reason for this is that earlier works in neuromarketing were published in top neuroscience journals and those of general interest. Later, as general marketing scholars started to appreciate and become more receptive to this approach, there was a shift from general interest or neuroscience journals to marketing journals. This shift was also facilitated by special issues that were dedicated to this approach (e.g., Camerer & Yoon, 2015; Shiv & Yoon, 2012). Despite the high entry barrier for most marketing researchers, the relationship between neuroscience and consumer research seems to be integrative, rather than competitive.

This development has been accompanied by a shift of focus from 'where' questions to more relevant 'what' questions (Chen, Nelson, & Hsu, 2015). Neuroscientists have been accumulating knowledge of the brain by localising different psychological processes. To contribute to theories of consumer behaviour, emphasis should now be placed on studying the underlying processes and the understanding of marketing phenomenon. One area that clearly stands out in terms of developing a theoretical understanding of a marketing phenomenon by integrating neuroscientific methods is branding.

Effect of brand in subjective experience

Destination branding is an important topic of tourism research (e.g., see Perkins, Khoo-Lattimore, & Arcodia, 2020 for a recent review). In the last six decades, marketing research has come a long way in understanding the phenomenon of branding, which is arguably one of the most important marketing variables. Marketing actions shape perceptions of experiences by inducing additional expectations of the experiences (Plassmann & Karmarkar, 2015). This rings true for tourism product branding, albeit with an added level of complexity. These findings also highlight the importance of branding for travel destinations, hotels, airlines or restaurants. Alternatively, the conceptual information about a brand triggers a top-down process that shapes the way a perception is evaluated (Shiv et al., 2005). Similar findings might occur in aspects of health and wellness tourism, where, for example, belief in the revitalising properties of spa water creates a wellness effect regardless of the water's actual efficacy.

Brand information may change self-reports of taste perceptions and preferences. This presents a methodological issue that is common to most consumer research, including within tourism, which relies primarily on self-report in probing participants' responses. This hints at the need to reinterpret some previous findings, such as those from the restaurant menu design literature, which has relied heavily on self-report (see Ip & Chark, 2023, for a review). Social desirability through self-report on tourists' eco-friendly choices and intended actions highlights the attitude–behaviour gap (Dahlgren & Hansen, 2015). Another assumption is that respondents are aware and able to articulate their attitudes, preferences, thoughts, feelings and intentions (Hsu, 2017). However, it has been argued that respondents are not conscious of most of their attitudes, preferences, thoughts, feelings and

intentions (Wilhelm & Grossman, 2010). Self-report emotions are more likely to be cognitive appraisals (Russell, 2003) and susceptible to emotional coping when participants repress their emotions (Bastiaansen et al., 2019).

The study that first gave support to the brand effect on subjective experience compared two well-known brands (McClure, Laibson, Loewenstein, & Cohen, 2004). Despite nearly identical chemical composition, Coke and Pepsi both attracted groups of consumers displaying strong preferences for one of these brands. Participants could not identify their favourite brands in a blind test when brand information was absent. This effect was also seen directly in the brain when the taste tests were administered during functional magnetic resonance imaging.

It is not surprising that the ventromedial prefrontal cortex, the part of the brain associated with the signalling of basic appetitive aspects of reward, predicted participants' taste preferences regardless of their self-report preferences. When brand information was disclosed, a neural circuit including the hippocampus, the thalamus, and the dorsal lateral prefrontal cortex was activated by Coca-Cola—the more established brand—but not Pepsi. These results strongly support the inference that while brand information may not change a customer's basic perception, it does shape their evaluation by triggering a top-down evaluation process. Branding, as cultural information, is an input that modulates reward-related brain responses, possibly through its emotional memory associations. Thus, the brand effect cannot be explained by a socially desirable response.

Importantly, the effect of branding on the consumption experience would not be known without neuroimaging tools; the purpose was to observe previously unobservable responses that go beyond self-report. Several neuroimaging studies have extended understanding of the brand effect on subjective experience to other consumption contexts (Deppe, Schwindt, Kugel, Plassmann, & Kenning, 2005; Erk, Spitzer, Wunderlich, Galley, & Walter, 2002; Esch et al., 2012; Plassmann, Kenning, & Ahlert, 2007; Pozharliev, Verbeke, Van Strien, & Bagozzi, 2015; Reimann, Castaño, Zaichkowsky, & Bechara, 2012; Schaefer, Berens, Heinze, & Rotte, 2006; Schaefer & Rotte, 2007a, 2007b). This phenomenon is as important for the development of tourism brands (e.g., airlines, hotel chains, travel retailers) as for the development of tangible goods.

Brand personality

Another thread of neuroimaging studies in branding has critically examined how consumers process brand information. Marketing scholars have argued that brands are perceived by consumers using a set of characteristics that are analogous to the way they perceive the personality of another person (Aaker, 1997). This brand personality framework has not only been very successful in consumer research but also had a profound impact on how practitioners position their brands. The same framework has been applied to study tourism destinations (Ekinci & Hosany, 2006). While this anthropomorphic framework is intuitive and useful, sceptics question whether the personality attributes of a brand are processed in the same way as personality attributes of people (Azoulay & Kapferer, 2003). For example, while the word 'reliable' can be used to describe both a person and a car, it is apparent that reliability means something fundamentally different in these two cases (Yoon, Gutchess, Feinberg, & Polk, 2006). Similarly, when a tourism destination is described as convivial, does it mean the same thing as describing a person as convivial?

This question cannot be answered using a self-report approach because the underlying processes are simply not consciously available to consumers. To answer this research question, Yoon et al. (2006) conducted a functional magnetic resonance imaging study in which participants made semantic judgements about brands and persons. The authors found that judgements about human traits and those of brands recruited two nonoverlapping neural networks, suggesting that the conceptualisation of brand personality should be refined. The processing of these two concepts is fundamentally different (Plassmann & Karmarkar, 2015). The dissociation of the neural networks for brand personalities and human personalities challenges the conventional view that brand associations can be conceptualised as similar to relationships with people (Plassmann et al., 2012).

To understand these findings better, Chen et al. (2015) ran a neuroimaging study in which participants were asked to think about several well-known brands, such as Apple, Google and Gucci. After the brain scanning session, the participants filled out a brand-personality questionnaire for the same set of brands. Using machine learning, the researchers decoded the whole-brain neuroimaging data into sets of regions that carried the neural signals of the psychological construct of brand personality. They found that the neural signals of brand personalities could be used to make out-of-sample predictions about the identities of the brands. Although brand personalities are not processed in the same way as human personalities (Yoon et al., 2006), they do exist a priori in consumers' minds (Camerer & Yoon, 2015).

Theoretical relevance and practical significance

In six decades, marketing has come a long way from the first documentation of branding's effect on taste perception (Allison & Uhl, 1964) to how the abstract concept of brand personality is processed in the brain (Chen et al., 2015). The reviewed neuroimaging studies contribute to our theoretical understanding of branding. First, they provide confirmatory evidence for the marketing phenomenon. The effect of branding on perceptions of the consumption experience has been shown to be not merely an artefact of socially desirable responses but a real effect that engages a network of brain regions associated with rewarding experiences and memory.

Second, these studies generate a more fundamental conceptualisation of underlying processes shaping consumer behaviour because neuroimaging tools allow a more direct observation of the neural processes involved. Yoon et al. (2012) asked whether it is useful to dissociate the underlying process if the decision behaviours are identical. They give a few reasons why the knowledge of the process is relevant theoretically. An understanding of the neural process may help generalise findings to other decision situations. This knowledge may help researchers understand how contextual influences interact with the neural process and inform the design of interventions.

Third, these studies refine existing conceptualisations such as brand personalities. While we know from Yoon et al. (2006) that brand personalities are not processed in the same way as human personalities are, they are still useful psychological constructs that are encoded in the brain (Chen et al., 2015). Fourth, neuroscientific methodologies enable a rigorous test of theories that are subject to the constraints of neuroscience (Yoon et al., 2012). Hypotheses about the underlying process, in addition to the behavioural outcomes, can be generated by following a realistic neurobiological mechanism. They can be tested using more direct observation of the neural processes. In particular, these processes may involve the role of emotion, which has to be dissociated from competing cognitive processes that take place simultaneously (Shiv, 2007). Testing of automated, implicit and nonconscious processes can be done in real time, which is not feasible using self-report methods (Camerer & Yoon, 2015). Furthermore, these measures may serve as mediators when testing consumer theories (Shiv et al., 2005).

Neuromarketing findings have the potential to inform tourism sector practices. Some researchers argue that neuroimaging tools may 'reveal information about consumer preferences that are unobtainable through conventional methods' (Ariely & Berns, 2010, p. 284) and 'measure what consumers really think and feel, rather than simply what they state' (Fisher, Chin, & Klitzman, 2010, p. 233). Indeed, many neuromarketing firms offer consultancy services using different biometric methods including eye tracking, electrodermal activity measures, facial coding, electroencephalography and functional magnetic resonance imaging (Smidts et al., 2014).

Neuromarketing in tourism research

It is likely that tourism research can benefit in ways similar to marketing from the integration of neuroscientific methods. For example, destination branding stands to benefit from neuromarketing findings about branding, which have immediate implications theoretically and practically. They could help us better understand tourist behaviour and identify the mechanisms underlying behavioural choices. More realistic theories of tourist behaviour could be built with greater understanding of the underlying processes.

Some interesting issues about destination branding could potentially be resolved using neuroscience. In particular, destination brand and destination image have been identified as interrelated concepts (Stepchenkova & Li, 2014). There is an ongoing debate about whether branding is the broader and more primitive concept (Li & Kaplanidou, 2013) that shapes destination image (Kneesel, Baloglu, & Millar, 2010), or the reverse, that image is more encompassing (Ekinci, 2003) and is the building block of destination brand (Tasci & Kozak, 2006). This chicken-or-egg problem cannot be resolved using a traditional approach. It is less of a concern in product marketing, but in tourism, destination image can arise independent of destination branding or as a direct consequence of tourism marketers' branding efforts (Park & Petrick, 2006). Functional magnetic resonance imaging can be used to see which parts of the neural pathways process the concepts of destination brand and destination image, respectively. Inferences can be drawn by comparing how early or late they are in the neural process. This biological realism reflects the psychological concept of an associative network in which memories of different concepts are organised (Stepchenkova & Li, 2014).

Destination personality also needs more attention from tourism marketers. While tourists have been found to be able to differentiate and articulate the personalities of different destinations, Aaker's brand personality model cannot be applied directly to capture the nuances of destination personalities (Murphy, Moscardo, & Benckendorff, 2007). In particular, only three dimensions – sincerity, excitement, and conviviality – have been found to describe the personalities of different destinations (Ekinci & Hosany, 2006). As in Yoon et al. (2006), neuroimaging could be applied to study how these different dimensions are represented and processed in the brain. The new evidence would probably guide the refinement and development of destination personality models.

Neuroimaging can also be used as a tool when developing tourism marketing materials. For example, electroencephalography has been applied to evaluate the effectiveness of destination promotion videos (Bastiaansen et al., 2018). It was found that when viewing pictures of a destination, previous exposure to successful promotional videos elicited early event-related potential components, which are linked to emotional response. Such emotional responses can be picked up by electroencephalography but not by self-report (Bastiaansen et al., 2022).

Neuroeconomics in tourism

Neuroeconomics focuses on the study of the neurobiological basis of decision making using a value-based approach (Rangel, Camerer, & Montague, 2008). The premise is that decision makers choose according to the subjective values of the available alternatives. Thus, the aim of research is often to identify the computation, encoding and representation processes of values in the brain. Three types of decision are often studied using this approach (Loewenstein, Rick, & Cohen, 2008): 1) decision making under risk and uncertainty (e.g., Chark & Chew, 2015), 2) intertemporal choice (e.g., McClure, Laibson, et al., 2004), and 3) social decision making (e.g., Zhong, Chark, Hsu, & Chew, 2016).

Theoretical relevance and tourism research agenda

The value-based approach calls for the modelling of behaviour by assuming that consumers are utility-maximising economic agents. One advantage of this approach is that some normative predictions can be made under general and standard assumptions. The deviations from these normative predictions can be quantified using computational models. Next, psychological and neural interpretations can be made. It has also been argued that neuroscience can help explain individual differences (Plassmann et al., 2015) and identify origins of heterogeneity in tourist behaviour (Venkatraman, Clithero, Fitzsimons, & Huettel, 2012). To this end, researchers may be more willing to include genetics and neuromodulators within their studies (Chark, 2018). Examples

from neuroeconomics help to illustrate how this expanded scope of investigation can shed new light on the study of human behaviour and, therefore, tourist behaviour.

The first example pertains to the group of studies on social decision making in which choices not only affect one's own welfare, as in the other two types, but also the welfare of others. This 'other regarding' behaviour has been studied in tourism contexts such as a concern for fairness in the sharing economy (Chark, 2019) and willingness to donate through cause-related marketing (Zhang, Hanks, & Line, 2019). Such interactive choice situations are often modelled using behavioural games.

Trust is an important concept in tourism research, for example in the context of online reviews (Sparks & Browning, 2011), shopping online for tourism products (Kim, Chung, & Lee, 2011), and the sharing economy (Ert, Fleischer, & Magen, 2016). However, it is an abstract concept and may have very different meanings across cultures and contexts. Behavioural games provide a way to operationalise an abstract concept like trust. In particular, the trust game (Berg, Dickhaut, & McCabe, 1995) has been studied extensively using functional magnetic resonance imaging.

One advantage of using behavioural games is that there are normative game theoretical predictions under certain assumptions. In general, decision makers are assumed to be selfish utility maximisers who can play the subgame with perfect equilibrium. Under these classical assumptions, when the responder maximises their utility, they should not return any positive amount to the sender. Anticipating this, the sender should also not send any positive amount to the responder. However, real consumers do not play the trust game as described by the game's theoretical prediction. Instead, around half of the endowment is often sent by the trustors, and the responders often return the favour by sending back more than the amount sent. These deviations capture the notions of trust and trustworthiness, respectively. In the value-based approach, subjective values of the alternatives can be modified to incorporate non-selfish and 'other regarding' considerations (e.g., Fehr & Schmidt, 1999) and be used in computational models of these choices (Kazinka, Vilares, & MacDonald, 2022).

A pioneering study was conducted using a multi-round trust game in which a fixed pair of sender and responder played the same game repeatedly (King-Casas et al., 2005). The researchers found that responders' intention to repay trust correlated with neural signals in the caudate head, which is implicated in encoding the signal of reward prediction error from reinforcement learning. Interestingly, there was a forward shift of this reward signal from the time when trust is revealed to the time when trust is anticipated. This temporal shift mirrors the findings of classical conditioning experiments (Schultz, Dayan, & Montague, 1997), indicating the development of a model of the trusting intention of their social partners. In a follow-up study, the same research group found that the computation of values during social exchange could be spatially represented along the cingulate cortex (Tomlin et al., 2006). Clearly, tourism experiences and satisfaction rely heavily on trust, reciprocity and social exchange, such as the trust between Airbnb host and guest, or the trust in fair value when bartering in a local market. There are many areas in which similar studies might be extended to the tourism context.

To gain a deeper understanding of the neurobiology of trust, one study examined the roles of neuromodulators in the trust game (Kosfeld, Heinrichs, Zak, Fischbacher, & Fehr, 2005). The researchers found that intranasal administration of oxytocin significantly increased trust as reflected in the amount sent by the senders compared with those receiving a placebo. Subsequently, a follow-up functional magnetic resonance imaging study was conducted with double-blind intranasal administration of oxytocin (Baumgartner, Heinrichs, Vonlanthen, Fischbacher, & Fehr, 2008). It was found that the effect of oxytocin on trusting behaviour was mediated by reduced fear processing in the amygdala and behavioural adaptations in the dorsal striatum. The literature on the trust game illustrates how the understanding of an abstract concept like trust can be quantified by computational models and studied by examining its neurobiological correlates at the brain level as well as the neuromodulator level. The study of the neurobiochemistry of tourist behaviour was proposed by Koc and Boz (2014), but few studies have answered this call.

The second example illustrates how genetic information can also be used to investigate individual neurobiological differences. A recent study examined the well-known phenomenon of familiarity bias in risk taking, which has implications for consumer decisions in finance and marketing (Chark et al., 2022).

It was found that a single nucleotide polymorphism – the most common type of genetic variation, in which a single building block of DNA (i.e., a nucleotide) is replaced with another – could predict consumers' predisposition to bias. Moreover, this genetic influence on behaviour was mediated by the amygdala's response to the novelty of the source of uncertainty. Specifically, the genotype predicted not only the behavioural tendency of familiarity bias but also neural sensitivity to novel stimuli. The amygdala is well known for its role in modulating vigilance and alertness. The genotype that had a higher amygdala sensitivity to novel stimuli also showed greater familiarity bias, as estimated by a computational model with inputs of subjective values and the novelty of the source of uncertainty. The study illustrates how neurobiology can impose extra constraints that help develop and test hypotheses.

The imaging genomics approach (Hariri & Weinberger, 2003; Thompson, Martin, & Wright, 2010), which combines genetics and neuroimaging, may be another fruitful way to study individual differences in tourist behaviour. The computational model also illustrates how a psychological construct such as familiarity bias can be captured quantitatively.

Familiarity bias is related to novelty seeking (Liao, Yeh, & Shimojo, 2011), which is a major driver of tourist behaviour (Lee & Crompton, 1992). Tourists also seek comfort in familiarity. For instance, tourists may not be familiar with, and thus not very receptive to, high-tech services in hotels and restaurants (e.g., the use of robots) or the use of artificial reality or virtual reality at heritage sites. The familiarity of global chains such as KFC and McDonald's provides an environment that can be trusted when a local restaurant is seen as too different. Understanding the relationship between familiarity, trust and tourist choices may aid the development of strategies for making the new and different less 'risky' and thus aid the development of poorer local economies.

Familiarity is also an important dimension of branding (Chark & Muthukrishnan, 2022). One study proposed that heritage sites could be advertised jointly with a familiar brand (Can, Ekinci, & Pino, 2021). The authors gave the example that in 2020, the Aegean Islands were promoted along with Greece, which is a very familiar destination brand. The co-branding strategy effectively transferred the brand equity of the familiar brand to the less familiar one. Neuroeconomic evidence suggests a mechanism through which this transfer happens and when it is more likely to happen.

Neuromanagement in tourism

Compared with neuromarketing and neuroeconomics, neuromanagement has been less researched. The tourism and hospitality industry has particular features such as high emotional labour, seasonality, low entry requirements and heavy workload in peak times, and topics such as leadership styles (e.g., Huertas-Valdivia, Gallego-Burín, & Lloréns-Montes, 2019) and ethical leadership (e.g., Dhar, 2016), which have attracted recent interest in tourism research, could be areas where neuromanagement is applied in tourism.

The study of individual differences is at the core of management research. To explain these differences, there is an accumulating literature using neuroscientific methods to pick up neurobiological differences among individuals (Scherbaum & Meade, 2013). For example, electroencephalography has been used to examine the neural correlates of inspirational leadership (Waldman, Balthazard, & Peterson, 2011). A management study found that inspirational leadership was associated with neural coherence, which is a metric of the interconnectedness of different brain regions. The measure was found to correlate with emotional balance and understanding others' emotions (Thatcher, North, & Biver, 2008).

Electroencephalography has also been adopted to study ethical leadership (Waldman et al., 2017). Brain activity in the default mode network has been found to predict ethical leadership. The neural effect on ethical leadership is mediated by relativism and this mediation effect is moderated by idealism. Given the recent interest in these topics in tourism research, it is likely that the identification of neural markers of these different dimensions in leadership will enrich our theoretical understanding of leadership among tourism managers and policy makers.

Another direction that is particularly relevant to tourism is emotional labour. In a recent paper, tourism researchers studied its consequences using functional magnetic resonance imaging (Choi et al., 2022). Frontline service employees have to perform deep acting. The emotional nature of this requirement often leads to stress and burnout (Han, Bonn, & Cho, 2016). Choi et al. (2022) studied the results of emotional labour among employees in the extreme case of customer incivility and found that employees developed an attenuated neural response to angry facial expressions. The blunted responses were interpreted by the authors as a habituation process and a way of coping with the emotional dissonance the employees experienced. Given that many emotional processes are either unconscious or difficult to articulate, neuroscientific methods provide a way in to the understanding of their effects on tourism workers.

Conclusions and avenues for neuroscience within tourism research

As technology advances, its cost may decrease and its operation may become simpler, which is likely to further encourage the application of neuroscience to tourism (Li, Lyu, et al., 2022). We predict that tourism research using neuroscience will advance considerably in the coming years and, through interdisciplinarity, will add much to the prevailing social science approach. Our curated collection and this review highlight how neuroscience can contribute to theoretical advances through building new interactions of cognition, affect and behaviour and establishing new hypotheses (Li, Lyu, et al., 2022). For example, combining electroencephalography with behavioural experiments to capture the activation of brain activity responses to a stimulus may help to develop new hypotheses (Plassmann et al., 2015). The interdisciplinary characteristics of neuroscience in tourism contribute to a more comprehensive and in-depth understanding of emotional responses, attitudes and behaviour within tourism studies.

Analysis of the review articles shows that eye tracking and electrodermal activity are the methods that have been used most widely in tourism research. Future research could apply other neuroscience methods such as electroencephalography and functional magnetic resonance imaging. Moreover, to improve the accuracy and explanatory power of research results, we suggest combining various neuroscience tools with traditional methods. The fact that most studies of neuroscience in tourism focus on advertising and the tourist experience implies that future studies can extend the application to other areas.

This paper proposes an agenda for incorporating neuroscience within tourism, drawing upon the related areas of neuromarketing, neuroeconomics and neuromanagement. By revisiting the features of tourism and the application of neuroscience in other non-tourism areas, we suggest four broad areas of tourism for future development.

First, tourism marketing continues to be a rich vein for further neuroscience integration. Marketing stimuli can affect tourists' cognitive and affective responses, which can further influence their attitudes and decision making, such as preferences and choices about tourism destinations, food on menus and hotels. Tourists' cognitive and affective responses can be measured by neuroscience methods, such as electroencephalography, electrodermal activity and eye tracking. As neuroscience techniques can distinguish between psychological processes, they can, for example, identify the differences in neural and psychological responses to hypothetical and real choices for tourism brands (Plassmann et al., 2015).

Second, opportunities for integration lie in neuroscience and tourist well-being. This can reveal the psychophysiological mechanism of the impacts of tourism on individual well-being, including subjective well-being, and help to understand the factors that contribute to happiness (McCabe & Johnson, 2013). Tourism can help to achieve escape from the everyday and from routine through relaxation in a novel place, which is likely to lead to increased happiness (Hao & Xiao, 2021). Most research on tourism

well-being has relied on a self-report approach. The introduction of neuroscience methods can improve the quality and explanatory power of the results. For example, using eye tracking and facial expression may better identify the extent to which factors such as social experience, novelty, escape and relaxation can influence well-being. Moreover, neuroscience can also explore the underlying neural mechanisms of tourism well-being connecting psychophysiological data, such as electrical activity in the brain, with tourists' emotions and their decisions.

Third, the application of neuroscience to sustainable tourism is an underexplored area. There is now a long tradition of encouraging sustainable behaviours in tourism organisations and in tourist consumption. Neuroscience tools are capable of measuring implicit processes that lead to moral consequences and are affected by self-deception and social desirability biases (Plassmann et al., 2015). Neuroscience can help us to understand the attitude–behaviour gap and develop campaigns/interventions that might improve the sustainability of the sector. For example, empathy may affect tourists' willingness to pay for tourism products and services with environmental and ethical attributes. A combination of eye tracking, electroencephalography and questionnaires can be useful in building a connection between neuro activity, empathy and tourists' willingness-to-pay behaviour.

Fourth, neuroscience could be applied to other areas involving tourists' perceptions, experience and behavioural intentions. Examples include understanding tourism service failure and recovery, high-touch versus high-tech in destinations and hotels, and niche markets such as film tourism, dark tourism and social tourism. All of these areas relate to individual differences, which can be better understood by neuroscience data combined with traditional approaches.

We conclude this section by proposing three major areas for tourism scholars to take into account when conducting neuroscience studies in tourism. First, there seem to be various roles that neuroscience can play in the tourism field. On one hand, neuroscience can be seen as merely complementary to traditional approaches. Previous review articles have focused mainly on the suitability, advantages, disadvantages and applications of neuroscience methods in tourism. Neuroscience techniques can be particularly useful when information such as neurological data is difficult to obtain by traditional approaches. On the other hand, it has been argued that the integration of neuroscience with tourism could lead to a paradigm shift and potentially to 'neurotourism' as a new branch of tourism studies (Ma et al., 2014). From that perspective, the integration of neuroscience in tourism is expected to bring a major change in concepts, methods and practices in the tourism field.

We argue that although the integration of neuroscience and tourism may not lead to a fundamental paradigm shift, it will bring new contributions to advance tourism knowledge beyond merely methodological contributions. There is promise that neuroscience can be of significant theoretical relevance and make a major contribution to tourism research. Most studies of neuroscience in tourism have focused on explaining neuroscience methods; their theoretical relevance has been less discussed. We therefore call for future studies in neuroscience to advance tourism knowledge through theoretical, rather than solely methodological, contributions.

Second, the challenges facing neuroscience techniques and possible solutions have not gained enough attention. For example, a common critique of neuroscience studies is their use of small samples due to the cost and time necessary to conduct experiments. However, the sample sizes of most neuroscience studies are comparable to those of behavioural studies due to the characteristics of the neuroscience experiments, which tend to be within-subject combined with repeated-measures designs (Plassmann et al., 2015). Moreover, meta-analysis has been applied to generalise neuroimaging findings to a large population, which increases statistical power in neuromarketing (Sung, Wilson, Yun, & Lee, 2020). In the future, meta-analytic statistical approaches can be conducted when there are sufficient studies in neuroscience in tourism.

A further challenge, noted in the review article by Li, Lyu, et al. (2022), is that neuroscience techniques cannot infer causal relationships. Instead, such techniques allow for the analysis of correlational relationships between psychophysiological data, such as brain activity or brain region, and related behaviour. This is useful for generating novel hypotheses. Follow-up behavioural studies could further test the causal relationships involved, complementing the neuroscience studies.

Third, there is a high barrier for tourism scholars as authors, reviewers and readers to employ, understand and appreciate neuroscience techniques, especially using electroencephalography, and functional magnetic resonance imaging. It is recommended that researchers in tourism collaborate with those in neuroscience who are capable of supporting the technical aspects of research (Lei et al., 2022). Other neuroscience methods, such as eye tracking and electrodermal activity, are easier for tourism scholars to apply, which may explain why they are more popular methods. However, the quality and reliability of these applications has been challenged. For example, in their review article, Li, Sung, et al. (2022) pointed out that some applications of electrodermal activity in tourism have fundamental flaws that have led to erroneous conclusions. We therefore call for more studies with appropriate and reliable neuroscience approaches applied to the tourism field.

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ShiNa Li is a professor in the School of Tourism Management, Sun Yat-Sen University.
Robin Chark is an associate professor in Integrated Resort and Tourism Management, Faculty of Business Administration, University of Macau.
Marcel Bastiaansen is a full professor in Leisure and Tourism Experience at Breda University of Applied Sciences and at Tilburg University.
Emma Wood is a professor in Events and Experiential Marketing, the School of Events, Tourism and Hospitality Management, Leeds Beckett University.