

# Bending and Bonding: A randomized controlled trial on the socio-psychobiological effects of spiritual versus secular yoga practice on social bonding

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## **Bending and Bonding: A randomized controlled trial on the socio-psychobiological effects of spiritual versus secular yoga practice on social bonding**

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### **Abstract**

Background: Participating in rituals gives rise to exceptional social bonding, but how this happens is not well understood. We assess the roles of four potential mechanisms activated during the rituals which may promote social bonding: (1) the spiritual nature of the ritual, (2) proto-transcendental experiences (i.e., the feeling of connection to something bigger than oneself), (3) mu-opioid receptor activation (measured via a pain proxy), and (4) positive affect.

Methods: In this pre-registered, longitudinal (5-week) experiment of ritual in controlled conditions, one group (N = 21) took part in spiritual yoga while another group (N = 19) took part in a behaviourally identical secular version.

Multilevel linear modelling was used to analyse the contribution of each of the proposed ritual mechanisms and their interactions. Results: Only positive affect and a proto-transcendental experience significantly predicted levels of social bonding. A follow-up Two-One-Sided-Test found significant evidence of ritual type (spiritual versus secular) having no effect on social bonding. Conclusions: These results suggest that rituals' social bonding effects are associated with changes in affect and the induction of feelings of connection to something bigger, but not the rituals' religious/spiritual nature.

**Keywords:** ritual; spiritual versus secular; yoga; social bonding; self-transcendence; positive affect; opioids

## **Declarations**

### Competing Interests and Funding

The study was funded by a grant from the Templeton Religion Trust (Grant number 0153). The funders did not determine the design, data collection, analysis or write-up of this article. The authors declare that they have no other conflict of interest.

### Ethics Approval

All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards. All participants who took part provided informed consent. The research conducted was approved by Coventry University's Ethics Committee (P76092).

### Data, Materials and/or Code Availability

All anonymised data, materials, research protocols, and analysis scripts can be found on the OSF at <https://osf.io/3dsyp/>

## **Bending and Bonding: A randomized controlled trial on the socio-psychobiological effects of spiritual versus secular yoga practice on social bonding**

### **Abstract**

*Background:* Participating in rituals gives rise to exceptional social bonding, but how this happens is not well understood. We assess the roles of four potential mechanisms activated during the rituals which may promote social bonding: (1) the spiritual nature of the ritual, (2) proto-transcendental experiences (i.e., the feeling of connection to something bigger than oneself), (3) mu-opioid receptor activation (measured via a pain proxy), and (4) positive affect. *Methods:* In this pre-registered, longitudinal (5-week) experiment of ritual in controlled conditions, one group (N = 21) took part in spiritual yoga while another group (N = 19) took part in a behaviourally identical secular version. Multilevel linear modelling was used to analyse the contribution of each of the proposed ritual mechanisms and their interactions. *Results:* Only positive affect and a proto-transcendental experience significantly predicted levels of social bonding. A follow-up Two-One-Sided-Test found significant evidence of ritual type (spiritual versus secular) having no effect on social bonding. *Conclusions:* These results suggest that rituals' social bonding effects are associated with changes in affect and the induction of feelings of connection to something bigger, but not the rituals' religious/spiritual nature.

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## Introduction

The formation of social connections and living in social groups – together comprising human sociality - are two of the most essential characteristics of being human (Taylor et al., 2002).

Crucially, human lives rely on the creation and maintenance of social bonds (Barton & Dunbar, 1997; 1991, 1998), which may be facilitated by rituals (Dunbar, 2013; Durkheim, 1912) . Indeed, religious rituals have previously been demonstrated to increase social bonding: Singh and colleagues (2020) found that Hindu Diwali celebration rituals lead to increases in social bonding, while Charles, van Mulukom, et al. (2020) found that attending Christian church services lead to increases in social bonding, via two biopsychological mechanisms – increased mu-opioid receptor activation and positive affect. Whether the activation of these mechanisms is specific to religious rituals, or whether religious rituals activate them particularly well is not yet clear, though early studies suggest that positive affect had a similar effect on social bonding in secular rituals at Sunday Assembly (Charles et al., 2021).

Evidence from historical and anthropological data, including USA 19<sup>th</sup> century Utopian communities and contemporary Israeli Kibbutzim, suggests that religious communes are more likely to survive than secular ones (Sosis, 2000) and that individuals feel a greater sense of belonging within the religious groups (Sosis & Ruffle, 2003). Does this effect extend to rituals? A few clinical-oriented longitudinal studies have contrasted the effects of spiritual versus secular meditation practice on pain tolerance and migraine frequency and severity, with the spiritual component consisting of God-oriented statements (e.g. ‘God is joy’, ‘God is love’) while the secular component was focused on self-attributes (e.g. ‘I am happy’, ‘I am good’) (Wachholtz et al., 2017; Wachholtz & Pargament, 2005, 2008). The results suggest that the effects of the spiritual intervention were consistently superior to the secular one, specifically greater pain tolerance and reduction of migraine frequency. Moreover, a study on religious recitation found that using a religious chant (‘hare krishna krishna krishna’) versus a pseudo-religious chant (‘sarva dasa sarva dasa’) led to greater reductions in anxiety and depression in the religious chant group (Wolf &

Abell, 2003). However, Charles and colleagues (2021) found no significant difference in levels of either social bonding or positive affect in participants who attended religious Christian church rituals as compared to secular Sunday Assembly rituals.

These studies present some interesting, albeit mixed (depending on the outcome measure), preliminary evidence that religious/spiritual practices/rituals may overall produce more beneficial effects than secular ones. For pain tolerance, the evidence is in favour of spiritual rituals, whereas for social bonding this is not the case. This previous evidence was collected from data archives, field studies, or within experimental individual non-ritualistic contexts. Here the aim was, for the first time, to conduct a randomized control experiment of the effects of a spiritual versus a secular ritual on social bonding, focusing on psychological (affect) and biological (pain) mechanisms. In addition, we examine self-transcendence (Thurfjell et al., 2019) as a potential mechanism through which certain religious/spiritual rituals may be better able to induce social bonding than secular rituals.

From an anthropological perspective, Durkheim (1912) has argued that rituals strengthen social ties through the stimulation of ‘collective effervescence’ by ritual behaviours. Collective effervescence is a “state of intense shared emotional activation and a sense of unison” that is produced through collective behaviour, such as rituals (Pizarro et al., 2022, p. 1). While a highly influential idea throughout the previous century of anthropology, collective effervescence has been notoriously hard to quantify as a psychological construct, and to elucidate its underlying biopsychological mechanisms (Xygalatas, 2015). Here we operationalise collective effervescence by focusing on the aspect that involves the dissolution or reduction of self-boundaries of the individuals during the ritual, which in turn allows the self to become connected to something bigger than oneself. This experience is also called *self-transcendence* (Yaden et al., 2017) when focused on the experience of a singular individual. While self-transcendence may often be considered a term reserved for intense religious experiences, it extends beyond the religious sphere, as secular individuals also experience self-transcendence (Newson et al., 2021; Thurfjell et al., 2019), where it

may be operationalised as awe (Chirico & Yaden, 2018; Van Cappellen, 2017). Awe, or a sense of intense wonder, is the experience of a strong positive emotion which includes feelings of connectedness and the perception of vastness, much like self-transcendence (Yaden et al., 2017). Despite this open nature of self-transcendence, it may be that religious and spiritual rituals are more geared towards a self-transcendence experience than secular equivalents. Indeed, Van Cappellen (2017) suggests that “At the heart of many religious and spiritual traditions is the aspiration to transcend the self to achieve a sense of connectedness with the world and/or with a Higher Power” (p. 254). This leads us to return to the important underlying question which has rarely been addressed: Is there something special about the religious/spiritual content of rituals – such as increased feelings of self-transcendence – which makes it more effective at inducing social bonding than secular equivalents?

In the present experimental study, we will operationalise the experience of self-transcendence as a ‘proto-transcendental experience’, as we want to acknowledge that the transcendental experiences that take place in natural contexts may be of an intensity a grade larger than what we may be able to induce in the laboratory. In essence, however, we aimed to measure a similar type of experience: an experience or state where individuals temporarily feel ‘elevated’ and connected to something vaster than oneself. Moreover, we use the term ‘spiritual’ here to conform to much of the literature comparing secular to religious/spiritual conditions, and to allow for the inclusion of those who identify with the growing ‘spiritual but not religious’ label (Ammerman, 2013). There is no ‘correct’ definition of ‘religious’ (Gombrich, 1996), only definitions that vary in usefulness (Berger, 1967/1981). The definition of ‘religious’ used for this study is based on Schilbrack’s (2013) definition, which suggests that behaviours conducted in direct relation to the super-empirical are religious. ‘Spiritual’, under this definition, is considered equivalent to ‘religious’, and as such only the term ‘spiritual’ will be used from here on, in order to conform to other literature on comparisons with secular equivalents.

The Durkheimian, anthropological account of rituals has been extended to include bio-physiological dimensions. Fieldwork demonstrated that high-intensity rituals are associated with shared high levels of arousal and heart rate synchrony (Konvalinka et al., 2011; Xygalatas, 2015; Xygalatas et al., 2011). In addition, there is a growing body of research showing that the kind of social bonding behaviours often found in rituals are associated with the release of *mu-opioids* (Charles, Farias, et al., 2020; Weinstein et al., 2016), endogenous opioids which have been hypothesized to be the neurochemical basis of bonding (Loseth et al., 2014; Machin & Dunbar, 2011; Panksepp et al., 1978; Panksepp et al., 1980). The human body's main mu-opioid receptor agonist (activator) is  $\beta$ -endorphin (see Benarroch (2012) for a full overview of endogenous opioid compounds).  $\beta$ -endorphin is best known for its role in providing post-exercise positive feelings often called the 'runner's high' (Boecker et al., 2008). Since mu-opioids act as a natural analgesic (Zubieta, Heitzeg, et al., 2003; Zubieta, Ketter, et al., 2003; Zubieta et al., 2001), pain threshold and/or pain tolerance have been used as proxy measures for  $\beta$ -endorphin release in experimental research (Charles, van Mulukom, et al., 2020; Cohen et al., 2010; Tarr et al., 2015; Tarr et al., 2016). These procedures have recently been used to assess the role of mu-opioids and social bonding across religious rituals in the UK and Brazil, with Christian and Afro-Brazilian participants (Charles, van Mulukom, et al., 2020). It was found that both positive affect and pain threshold predicted strength of social bonding following religious rituals (Charles, van Mulukom, et al., 2020). The role of mu-opioids has also been tested in a religious ritual by using a pharmacological antagonist which blocks the effects of mu-opioids. In a double-blind field experiment, participants who took the opioid antagonist Naltrexone before the ritual reported significantly lower social bonding, compared to individuals taking part in the same ritual who took a placebo (Charles, Farias, et al., 2020).

In addition to mu-opioid effects, rituals have been associated with an increase in wellbeing (Van Cappellen, Toth-Gauthier, et al., 2016), potentially through an increase in positive affect (Fredrickson, 2002), which in turn may contribute to social bonding (Mauss et al., 2011; Waugh &



Fredrickson, 2006). Positive emotions have been previously associated with states of self-transcendence and Durkheimian collective effervescence (Van Cappellen, Way, et al., 2016), so it is possible that positive affect plays a significant role as a mechanism underlying the social bonding function of rituals.

In the current, pre-registered study ([https://osf.io/892zf/?view\\_only=f824b98755084d50b57da9420543ad42](https://osf.io/892zf/?view_only=f824b98755084d50b57da9420543ad42)), we seek to examine whether religious/spiritual rituals are more effective at inducing social bonding than secular equivalents, and assess four potential mechanisms of rituals that may support social bonding, and their interactions: (1) the spiritual nature of the ritual, (2) proto-transcendental experiences, (3) mu-opioid receptor activation (measured via a pain proxy), and (4) positive affect. We examine these mechanisms in the ritual of *Hatha* yoga practice. Hatha yoga practice is a type of yoga, but is distinct from classical yoga (aka *Raja* yoga): Where the overarching philosophy of classical yoga is largely oriented around the *cognitive* goal of achieving self-regulation and includes the teaching of ethical principles ('*yamas*' and '*niyamas*'), as well as meditation techniques ('*pratyahara*, *dharana*, *dhyana*, and *samadhi*'), Hatha yoga is mainly focused on the practice of taking on postures ('*asanas*'; see Feuerstein, 2022; Gard et al., 2014; Matko et al., 2021). Moreover, Hatha yoga and other types of posture-based yoga seems to improve fitness and increase positive emotional states, while reducing negative emotional states, whereas other forms of yoga only lead to greater levels of awareness and lower levels of stress (Büssing et al., 2012).

We chose Hatha yoga for three reasons: Firstly, Hatha yoga, as a physical practice of taking on postures, conforms to both Hobson et al.'s (2018) definition of a ritual, as it has (a) repeated, predefined posture sequences that (b) are embedded in a larger system of symbolism and (c) these postures lack a clear, direct, instrumental purpose, and Rappaport's (Rappaport, 1999) definition of ritual, in that it is the formal performance of a set of more-or-less invariant behaviours encoded by someone else, as well as other definitions of ritual (e.g., Charles, 2021, p. 26). Secondly, this Hindu-based practice is currently practiced by many in the West in a way that is removed of its

religious aspects to encourage a more physiotherapeutic or exercise focus (Yadav et al., 2012), but its spiritual basis can still be emphasised. Thirdly, there is research linking Hatha yoga practice to the release of  $\beta$ -endorphin (Suri et al., 2017; Yadav et al., 2012), and with increases in positive affect (Kiecolt-Glaser et al., 2010), which suggests that using Hatha yoga in a controlled social-based experiment might be able to elicit a powerful effect similar to that of rituals in its ‘natural’ context. For ease, just term ‘yoga’ will be used in the remainder of this article in reference to Hatha yoga; if other subtypes of yoga are intended, they will be specified.

In sum, the current study sought to better understand the socio-psychobiological mechanisms of rituals that may lead to social bonding, by directly contrasting spiritual and secular versions of the same behaviours in a controlled setting – during a five-week yoga course. Levels of social bonding, affect, and pain tolerance (as a proxy for central mu-opioid activation) were measured before and after the sessions. Five key hypotheses were tested in this study:

1. Taking part in ritual-like group yoga sessions will lead to increases in social bonding with other attendees.
2. A proto-transcendental experience will be greater in the spiritual yoga condition compared to secular yoga.
3. Social bonding will be higher in those taking part in the spiritual yoga than those taking part in the secular yoga.
4. Changes in self-reported measures of social bonding will be predicted by changes in the mu-opioid proxy (assessed as a pain tolerance test).
5. Positive affect will positively predict social bonding.

## **Methods**

### **Participants**

Participants between the age of 18 and 65, who had never practiced yoga, were included in this study. Those with a diagnoses of arthritis (Kosek & Ordeberg, 2000; Lee et al., 2011; Wessel,

1995), diabetes (Lee & McCarty, 1992; Themistocleous et al., 2016), ADD/ADHD (Stickley et al., 2016; Treister et al., 2015) were excluded from the study due to changes in pain perception reported by those with such diagnoses. Given the required physical exercise of the yoga session those with musculoskeletal, blood clotting or circulatory issues were also excluded from the study.

A total of 52 participants (one non-binary, 10 male,  $M_{age} = 29.1$ ,  $SD_{age} = 14.32$ ; 13 non-religious (NR); two Hindus, two Sikhs, two Buddhists, six Spiritual but not Religious (SBNR) and six who opted not to say (ONTS), the remaining 21 were Christian) took part in the study. Twenty-nine participants (six male; two NR, one Sikh, four SBNR, two Hindus, three ONTSs, eleven Christian) were randomly assigned to the spiritual yoga condition and 23 participants (4 male, 1 non-binary; six NR, one Sikh, two Buddhists, two SBNR, three ONTSs, and nine Christian) were randomly assigned to the secular yoga condition. Forty participants (8 male, 1 non-binary,  $M_{age} = 29.5$ ,  $SD_{age} = 15.68$ ) attended all five weeks of yoga (did not attend all sessions: seven Christians, one NRs, three ONTSs). Of these, 21 participants (5 male,  $M_{age} = 27.2$ ,  $SD_{age} = 15.39$ ) were assigned to the spiritual condition (did not attend all sessions: five Christians, one NRs, two ONTSs) and 19 participants (3 male, 1 non-binary,  $M_{age} = 32.4$ ,  $SD_{age} = 15.97$ ) were assigned to the secular condition (did not attend all sessions: two Christians, one NRs, one ONTS; see Figure 1). There was no significant difference in age ( $t(49) = 1.65$ ,  $p = .104$ ), gender ( $\chi^2(1) = <.001$ ,  $p >.999$ ), baseline levels of religiosity (out of 6; spiritual group,  $M = 2.5$ ,  $SD = 2.18$ , secular group,  $M = 1.8$ ,  $SD = 1.50$ ,  $t(36.9) = 1.19$ ,  $p = .241$ , both fairly low) or spirituality (out of 6; spiritual group,  $M = 3.1$ ,  $SD = 1.84$ , secular group,  $M = 3.0$ ,  $SD = 1.35$ ,  $t(44) = 0.10$ ,  $p = .924$ , both moderate out of 6) between participants assigned to the two yoga conditions.

[INCLUDE FIG 1 ABOUT HERE]

**Fig. 1** A flow chart showing attendance of yoga for participants assigned to each condition. In total, 21 of 29 participants attended all five weeks of spiritual yoga, and 19 of 23 participants attended all five weeks of secular yoga

## Materials

*Social bonding measures.* The historic assessment of social bonding has been criticised for being inconsistent (Holt-Lunstad et al., 2010). Holt-Lunstad et al. (2010) have stated that the measure of *quality* of a social bond is particularly rare in the literature. Those that have provided a measure of quality have often only measured a single aspect of social bonding, not the entire construct (Charles, 2021). As such, more recent research has used a composite measure of these disparate social bonding measures that each measured one of six major components of the latent variable, social bonding (see Charles, 2021, pp. 64-67; Charles, Farias, et al., 2020; Charles et al., 2021). This six-item measure has been shown to measure a unidimensional construct of social bonding (Charles, Farias, et al., 2020) and have high levels of internal reliability (Charles, Farias, et al., 2020; Charles et al., 2021). As such, we used the same measure in this study. Six questions were used to measure social bonding. Five of these were measured on a 7-point Likert scale, from ‘1’ “not at all” to ‘7’ “extremely”: (1) “At this moment, how connected do you feel to the people in this yoga session?” (adapted from Wiltermuth & Heath, 2009); (2) “At this moment, how emotionally close do you feel to the other members of this yoga session as a whole” (adapted from Inagaki & Eisenberger, 2013; Inagaki et al., 2019b); (3) “Thinking about everyone in your yoga session now, how much do you trust the others in this group?” (adapted from Kosfeld et al., 2005); (4) “How much do you like the people in this yoga session overall?” (adapted from Hove & Risen, 2009); and (5) “Thinking about everyone in this yoga session now, do you feel you have a lot in common with others in this congregation?” (adapted from Valdesolo & DeSteno, 2011). The last question was the pictorial Inclusions of Others in Self scale (IOS; Aron et al., 1992), which is a 7-point scale that uses Venn-diagrams to illustrate how closely one identifies with others, where ‘1’ signifies mostly separate identity and ‘7’ signifies extremely close identity. Answers to these questions were averaged into a single social bonding score (reliability = .80, 95% CI [.73, .87], see (Laenen et al., 2007) and supplemental information, section S2, for information about the longitudinal reliability

measure). For a full version of the questionnaires, see the online materials

([https://osf.io/n54mz/?view\\_only=f824b98755084d50b57da9420543ad42](https://osf.io/n54mz/?view_only=f824b98755084d50b57da9420543ad42)).

*Pain tolerance.* The wall-sit measure, also known as a wall squat, is an endurance exercise that requires participants to hold a sitting position for as long as possible while against a wall (Wilkerson et al., 2012). It has been used in previous work as a measure of pain tolerance, measured by the length of time one can hold the wall-sit, as the endurance test becomes painful after a short period of time (2016; Johnson & Dunbar, 2016; Pearce et al., 2016), with high test-retest reliability (Bruce et al., 2017).

*Positive and Negative Affect.* The Positive And Negative Affect Scale (PANAS; Watson et al., 1988) was used to collect data on the emotional state of participants. The PANAS asks participants to say how much they are feeling 20 emotions (10 positive, 10 negative) “at this moment” measured on a 6-point Likert scale, from zero to five, where zero is “not at all” and five is “very much”. Examples of positive emotions include ‘Strong’, ‘Proud’, and ‘Attentive’, examples of negative emotions include ‘Jittery’, ‘Ashamed’ and ‘Upset’. Watson and colleagues (1988) suggest the use of the sum values for the 10 emotions for both positive and negative to provide two scores: the sum of the scores for positive emotions, PANAS+ (reliability = .71, 95% CI [.58, .77]), and the sum of scores for the negative emotions, PANAS– (reliability = .51, 95% CI [.36, .58]).

*Proto-transcendental experience.* After each session participants were asked the question “During today’s meeting, did you feel connected to something bigger than yourself, like the universe, and/or feel a sense of awe or wonder?”. This was measured on a seven-point Likert scale from “Not at all” (1) to “Extremely” (7), with the following intermediate values and labels: Very slightly (2), A little (3), Moderately (4), Quite a bit (5), and Very much (6). We formulated this item this way as to capture the individual experience of collective effervescence through the following aspects: (i) an experience of something which is bigger than oneself (cf. vastness subscale of the AWE-S, Yaden et al., 2017), (ii) feeling of connectedness (cf. connectedness subscale of the AWE-S, Yaden et al., 2017), (iii) the universe, so as to distinguish between feeling connected to the

physical group or people around you versus something more abstract (cf. a Higher Power, Van Cappellen, 2017), (iv) explicit link to awe and wonder, as a way to emphasise the intense feelings that are part of self-transcendence and collective effervescence.

### **Yoga equipment**

Participants were all provided with a yoga mat, and with the same yoga training top to wear for the experiment. The purpose of this was to allow this paradigm to mimic other rituals (e.g. religious services, sporting events or music concerts), which often have specific clothing that attendees wear to signify they are part of a group.

## **Procedure**

### **Participant recruitment**

The study was advertised through physical poster advertisements as well as online on social media, and via mailing lists of various universities. Participants were told they would be paid £50 to take part in five weeks of yoga, and their travel expenses were also to be covered. Participants were provided with the information sheet and consent form to sign in advance of attendance. Once these had been signed, they filled in a short online survey to ensure that they were naïve to yoga (an exclusion criterion), as well as getting background demographic data and contact details, to send reminders about the yoga sessions. If, at this stage, it was found they had previous experience of yoga, the participant was informed that they were not eligible for the study. Once an eligible participant had completed this survey, they were randomly allocated to either the spiritual or secular condition by using a computerised dice-rolling simulator. The dice-rolling simulator simulated the roll of a six-sided die. If it rolled a one, two or three, they were allocated to the secular condition. If it rolled a four, five or six, they were allocated to the spiritual condition.

## Yoga sessions

The yoga sessions were designed by an instructor with over 30 years' experience (A.S.), who trains other yoga teachers, and also is an author of spiritual books on yoga (e.g., Saraswati, 2003; Saraswati, 2009). The instructor was not aware of the specific hypotheses of the study until after designing/running the sessions. The sessions involved opening with warm-up movements from a standing pose, followed by moving through multiple poses that are common in Hatha yoga. The sessions then ended with a 6-minute cool-down/relaxation period, which involved participants lying in corpse pose (i.e., straight on their backs) or in the Alexander resting pose (i.e., on their back with their knees off the ground), based on what was more comfortable for the participant.

The sessions were planned so that the behaviours in both the spiritual and the secular forms of yoga were identical, including any time spent focused on breathing, with the framing of the behaviours as the only difference between the two session types. Details of the schedule for the secular and spiritual sessions can be found on the online materials ([https://osf.io/n54mz/?view\\_only=f824b98755084d50b57da9420543ad42](https://osf.io/n54mz/?view_only=f824b98755084d50b57da9420543ad42)). For an example of how the sessions differ, on pages 3-4 of the “Class 1 – Secular Yoga” document, in the section labelled “Tiger posture to goose posture to salutations posture”, it states that the “tutor engages Participants’ attention and directs it to the muscles being engaged and being stretched.” (p. 4). Conversely, in the “Class 1 – Spiritual Yoga” document, there is an additional section stating “Alongside the physical sensations of the movement, participants will be invited to be aware of the way in which the attention moves from thought to physical sensation. The tutor will explain that in this attention or awareness is known as the ‘buddhi’ in Yoga.” (p. 4). This term is often referred to as the session develops with increased suggestions to move beyond the physical and psychological dimensions. For example, during the corpse or Śavāsana pose, the teacher chants and explains verses 3 and 5 of Patanjali’s *Yoga Sutras* (Satchidananda, 1978), emphasizing that in yoga ‘we are seeking what is behind the physical and psychological: the subtle unknown from which both emerged.’ (see ‘Class 1 - Spiritual Yoga’ document on the OSF, p. 5).

There were other differences between the spiritual and secular sessions: the postures in each of the sessions were given either their traditional yoga name or secular name for the spiritual or secular sessions, respectively (e.g. Vyagrāsana v.s. Tiger Pose or Pranamāsana v.s. Salutations Posture). This also helped provide a level of spiritual meaning to each pose in the spiritual sessions that was not present in the secular versions, much like how certain religious rituals contain specific terminology that relates only to the relevant ritual which one would need to become accustomed with before knowing what it meant, such as the ‘Eucharist’ (i.e. consumption of bread and wine, also known as ‘holy communion’) in Christianity, or the ‘chibuv hamitzvah’ (i.e. the act of kissing the Torah, literally translating to ‘showing an appreciation for the commandments’) in Judaism.

#### Before and after the sessions

Upon arrival to a session, participants changed into the provided yoga top and signed the informed consent form. They were then asked to fill in the pre-session questionnaire and take the wall-sit measure. This all occurred within 30 minutes of the start of the session (depending on who was assessed first for the wall-sit, and how long they took to change, this could vary from ~25mins before a session to ~1 min before the session). The participants took part in the 1-hour yoga session, and then filled in the post-session section of the questionnaire and re-took the wall-sit measure. Only after measures were re-taken and the post-session section of the questionnaire was completed were the participants then allowed to change.<sup>1</sup>

Session timeslots were two hours long, with 30 minutes before and after the session to ensure participants had time to change into/out of the yoga tops provided, and to fill in the questionnaire and take the wall-sit measure.

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<sup>1</sup> A plan to measure levels of  $\beta$ -endorphin in the blood serum before and after sessions one, three and five had been pre-registered. However, due to technical issues, this was not possible. See supplemental information (section S1) for more details. Also, the upper-values on the times it took to complete the post-session measures were on weeks 1, 3, and 5 when blood samples were also being taken, adding more time to data collection than in weeks 2 and 4. On weeks 2 and 4, all data collection was conducted within 10 minutes of the end of the sessions



## Data analysis

Scale reliability for longitudinal data was not calculated in the same way as for studies that measure a construct on a single occasion, or in a single day (e.g.  $\alpha$  or  $\omega$ ). The method for calculating reliability for all the grouped measures (averaged or summed) used in the article was completed using the CorrMixed R package (Van der Elst et al., 2016). Full details and the rationale for using this method are outlined in S2 of the supplementary information.

Multiple models of varying complexity (i.e. with different numbers of fixed and random effects and control variables) were constructed using a maximum likelihood method and AICc values to determine which models best account for the data for the research question being asked. Once a model that best fits the data is determined, the Luke (2017) method was conducted on the most parsimonious model to provide  $p$ -values for the fixed effects, which can be interpreted in a similar way to  $p$ -values provided by a regression (For a full explanation of this method, see the supplemental information section S3). The model creation process is documented in the supplementary information (section S4), and the precise analysis methods can be found in the R analysis script. All variables were grand-mean centred and standardised before analysis.

## Results

### Hypothesis testing

First, data was visualised to understand how relevant dependent variables changed over time (see Figure 2, 3, and 4). Next, the hypothesis that taking part in yoga (irrespective of the condition) would lead to an increase in social bonding was investigated. The most parsimonious model produced to test this hypothesis included both measures of time (pre-session-to-post-session \* week of yoga interaction), which allowed random effects for participants. The result of the Luke (2017) method for determining the fixed-effects  $p$ -values are listed in Table 1, Model A (Models B and C are explained later in the results section). The results show that social bonding increased (i) from before to after each session (a significant main effect of measurement occasion) and (ii) each week

(a significant main effect of week), and that (iii) the level to which this increase happened was lower each week, compared to the first week (a significant measurement occasion \* week interaction; see supplementary figure C).

[INCLUDE FIG 2 ABOUT HERE]

**Fig. 2** The mean social bonding score (full possible range 1-7) over time, with **a)** the data for participants in the secular yoga condition, and **b)** the data for participants in the spiritual yoga condition. Error bars show  $\pm 1$  standard error from the mean

[INCLUDE FIG 3 ABOUT HERE]

**Fig. 3** The mean **A)** PANAS+ and **B)** PANAS- scores over time in both the secular and spiritual yoga conditions. Error bars show  $\pm 1$  standard error from the mean.

[INCLUDE FIG 4 ABOUT HERE]

**Fig. 4** The mean pain tolerance duration over time **A)** shows the data for participants in the secular yoga condition, **B)** shows the data for participants in the spiritual yoga condition. Error bars show  $\pm 1$  standard error from the mean

**Table 1.**

*Table with the Fixed-Effects outputs of the three multilevel models predicting social bonding.*

Variable (level)	Model A			Model B			Model C		
	Estimate (SE)	95% CI	<i>p</i>	Estimate (SE)	95% CI	<i>p</i>	Estimate (SE)	95% CI	<i>p</i>
(Constant)	-.86 (.13)	[-.99, -.73]	<.001	-.84	[-.96, -.71]	<.001	-.74 (.14)	[-.88, -.60]	<.001
Measurement Occasion (1)	.73 (.08)	[.65, .81]	<.001	.68 (.08)	[.61, .76]	<.001	.68 (.07)	[.62, .75]	<.001
Week 2 (1)	.61 (.08)	[.53, .70]	<.001	.66 (.08)	[.58, .74]	<.001	.58 (.07)	[.51, .65]	<.001
Week 3 (1)	.87 (.08)	[.78, .95]	<.001	.95 (.08)	[.87, 1.03]	<.001	.86 (.07)	[.79, .93]	<.001

<i>Week 4 (1)</i>	.93 (.08)	[.85, 1.02]	<.001	1.01	[.93, 1.10]	<.001	0.90 (.07)	[.83, .97]	<.001
<i>Week 5 (1)</i>	1.08 (.08)	[1.00, 1.17]	<.001	1.15	[1.07, 1.23]	<.001	1.04 (.07)	[.97, 1.12]	<.001
<i>Measurement Occasion * Week 2 (1)</i>	-.47 (.11)	[-.58, -.35]	<.001	-.47 (.10)	[-.57, -.37]	<.001	-.47 (.09)	[-.56, -.38]	<.001
<i>Measurement Occasion * Week 3 (1)</i>	-.56 (.12)	[-.67, -.44]	<.001	-.58 (.10)	[-.69, -.48]	<.001	-.59 (.09)	[-.68, -.50]	<.001
<i>Measurement Occasion * Week 4 (1)</i>	-.44 (.12)	[-.56, -.33]	<.001	-.50 (.10)	[-.60, -.39]	<.001	-.48 (.09)	[-.57, -.38]	<.001
<i>Measurement Occasion * Week 5 (1)</i>	-.46 (.12)	[-.58, -.34]	<.001	-.49 (.11)	[-.60, -.38]	<.001	-.49 (.09)	[-.58, -.40]	<.001
<i>PANAS+ (1<sup>a</sup>)</i>				.22 (.05)	[.17, .27]	<.001	.20 (.04)	[.15, .24]	<.001
<i>PANAS- (1<sup>a</sup>)</i>				-.01 (.04)	[-.05, .03]	.829	-.02 (.03)	[-.04, .01]	.531
<i>Pain Tolerance (1)</i>							.04 (.03)	[.01, .06]	.142
<i>Transcendental Experience (1<sup>a</sup>)</i>							.129 (.06)	[.23, .35]	<.001
<i>Yoga Group (2)</i>							-.13 (.16)	[-.29, .03]	.427
Observations	468			468			468		
(Participants)	(52)			(52)			(52)		
AICc	681.5			625.4			529.1		
dAICc	-20.5			-5.0			-1.8		
Marginal $R^2$ <sup>b</sup>	0.136			0.178			0.314		
Conditional $R^2$ <sup>b</sup>	0.833			0.881			0.895		

Note. **Model A** shows the model testing hypothesis 1, that social bonding would increase from before to after yoga, irrespective of group. **Model B** shows the model testing hypothesis 5, that affect would predict social bonding. **Model C** shows the follow-up analysis demonstrating the most parsimonious model with the available variables. Multilevel model  $p$ -values were generated with the Luke (2017) method, with the Satterthwaite (1941) correction applied, AICc values are calculated during the Maximum Likelihood method at the model comparison stage, and dAICc is the difference in AICc value from the next most parsimonious model in the comparison process.

<sup>a</sup> allowed to vary within participant (i.e., also a random effect)

<sup>b</sup> Marginal  $R^2$  is the amount of variance explained by only the fixed effects, the Conditional  $R^2$  is the amount of variance explained by the full model, including the random effects structure, and are calculated as shown in the equations below.

$$\text{Marginal } R^2 = \frac{\sigma_f^2}{\sigma_f^2 + \sum_{l=1}^u (\sigma_l^2) + \sigma_e^2 + \sigma_d^2}$$

$$\text{Conditional } R^2 = \frac{\sigma_f^2 + \sum_{l=1}^u (\sigma_l^2)}{\sigma_f^2 + \sum_{l=1}^u (\sigma_l^2) + \sigma_e^2 + \sigma_d^2}$$

Next, it was tested whether there was a difference in proto-transcendental experience between the group conditions (secular vs. spiritual, see Figure 5). A significant difference between spiritual and secular yoga on this measure was found. Moreover, proto-transcendental experience increased each week across participants in both groups, see Table 2. It was also found that the difference between the spiritual and secular yoga conditions on this measure became significantly smaller than the first week for the second, third and fifth week (a significant week\*yoga group type interaction).

[INSERT FIG 5 ABOUT HERE]

**Fig. 5** Graph showing the self-rated connection to something bigger than oneself (possible range 1-7) in both secular yoga (blue circles) and spiritual yoga (orange diamonds) participants. Error bars show  $\pm 1$  standard error from the mean.

To test the third hypothesis, that social bonding will be higher in those taking part in the spiritual yoga than those taking part in the secular yoga, a fixed effect of yoga group type (secular v.s. spiritual) was added to the model brought forward from hypothesis 1; first looking for a simple fixed effect ( $AICc = 683.5$ ) and then looking for a possible interaction between yoga group type and week ( $AICc = 698.1$ ). Including yoga group type in the model in any way resulted in a less parsimonious model than when not included ( $dAICc = 2.0$ ), suggesting that yoga group type does not provide any significant improvement to the model. To confirm this, the  $p$ -values for the fixed effects for the most parsimonious model that still included yoga group type were produced using the Luke (2017) method and showed that yoga group type was not a significant effect (estimate = .06,  $t(50.45) = .26$ ,  $p = .79$ ). This means that, while there was a significant difference between yoga groups in proto-transcendental experience, this did not lead to differences in social bonding between the yoga groups.

**Table 2.**

*Fixed-Effects output for the final model predicting proto-transcendental experience.*

<b>Variable</b>	<b>Estimate</b>	<b>SE</b>	<b>95% CI</b>	<b><i>t</i></b>	<b><i>Sig. (p)</i></b>
(Constant)	-.56	.19	[-.75, -.37]	-2.92	.005
<i>Yoga Group</i>	.78	.26	[.52, 1.04]	3.05	.003
<i>Week 2</i>	.40	.10	[.30, .50]	3.85	<.001
<i>Week 3</i>	.39	.11	[.28, .50]	3.62	<.001
<i>Week 4</i>	.13	.11	[.03, .24]	1.26	.210
<i>Week 5</i>	.36	.11	[.25, .47]	3.35	.001
<i>Yoga Group * Week 2</i>	-.47	.14	[-.61, -.33]	-3.42	<.001
<i>Yoga Group * Week 3</i>	-.52	.14	[-.66, -.38]	-3.64	<.001
<i>Yoga Group * Week 4</i>	-.10	.14	[-.24, .04]	-0.71	.481
<i>Yoga Group * Week 5</i>	-.30	.14	[-.44, -.15]	-2.07	.039

To test the fourth hypothesis, that the pain tolerance proxy of mu-opioids would positively predict social bonding, the wall-sit measure was added into the model brought forward from hypothesis 1 in various possible combinations (i.e., to allow for an interaction effect, to allow the wall-sit value to vary by participant, etc.). The most parsimonious model included a single fixed effect of wall-sit (without interactions) and allowed the wall-sit value to vary by participant ( $dAICc = 2.8$ ). While including it in the model did improve model parsimony, the fixed-effect of pain tolerance, measured via the wall-sit, did not significantly predict change in social bonding (estimate = 0.06,  $t(20.39) = 1.26$ ,  $p = .222$ ). The visual representation of the data (see supplementary figure D) suggests that outliers potentially stopped pain tolerance from being a significant predictor. To explore whether this was the case, outliers (calculated using the Tukey's fences criterion of the relative quartile  $\pm 1.5$  IQR) were removed, and the model structure re-analysed. However, it was still found that wall-sit did not significantly predict change in social bonding (estimate = 0.09,  $t(418.60) = 1.54$ ,  $p = .124$ ).

The final hypothesis for this study was that positive affect would positively predict social bonding. To test this, both PANAS subscales were included into the model brought forward from hypothesis 1 in various combinations to assess model fit. The best model included both PANAS+ and PANAS- as fixed effects and allowed both PANAS+ and PANAS- to vary within participants, but without interacting with one another. As seen in the output of the fixed-effects shown in Table 1, labelled as Model B, PANAS+ significantly predicted social bonding scores in line with our hypothesis, but PANAS- scores did not.

### Follow-up analyses

As well as main hypotheses, the multilevel model approach allowed us to conduct follow-up analyses based on previous models. To do this, a series of possible overall models were created that incorporated all the variables previously assessed (affect, session type, wall-sit, and time) in various combinations, as well as demographic variables of age and gender, to predict social bonding. The best fitting model was one that included pain tolerance, PANAS+, PANAS-, proto-transcendental experience, session type, and an interaction between the time variables as fixed effects, while allowing PANAS+, PANAS-, and proto-transcendental experience to vary within participants (see supplemental Table I for full model comparisons). The final output of this model (Table 1, Model C) found that that positive affect, and proto-transcendental experience both significantly predicted social bonding, as did all the time variables. No other variables were significant. This shows that there was no significant effect of yoga group type on social bonding, even though a feeling of proto-transcendental experience did predict levels of social bonding.

Two-one-sided tests (TOST) of equivalence are possible within mixed-effects models (Isager, 2019). Using the method laid out by Isager (2019), using Model C presented in Table 1 (the most parsimonious model to include session type as a variable), we were able to assess whether there was significant evidence of there being no difference in effect caused by the religious component of the ritual. In cognitive sciences, the median moderate effect size reported is  $d = 0.46$

(Szucs & Ioannidis, 2017, 2021). It is advised that one use moderate effect size estimates as the cut-offs for smallest effect size of interest values when conducting a TOST (see Isager, 2019). Using bounds of  $d = +/- .46$ , a mixed-effects TOST found that the estimate generated by Model C for the type of type of yoga (religious versus secular) of  $-.13$  ( $SE = .16$ ) was significantly lower than the upper bound ( $t(51.22) = -3.77, p < .001$ ) and was significantly greater than the lower bound ( $t(51.22) = 2.13, p = .019$ ). This suggests that there is significant evidence that there is no effect of session type (spiritual versus secular) on social bonding.

## Discussion

Religious rituals are a human universal (Brown, 2000), thought to be so widespread because of their ability to create the social bonds that enable human societies to thrive (Alcorta & Sosis, 2005; 2013). Although there is some evidence supporting the idea that religious ritual plays a role in human social bonding (Charles, van Mulukom, et al., 2020; Singh et al., 2020), there had been, to the authors' knowledge, no studies in controlled conditions comparing the effects of religious or spiritual ritual aspects on social bonding to the effects of secular equivalents. Here, the authors present the first study that sought to compare a spiritual ritual and a behaviourally identical secular ritual in controlled conditions in relation to social bonding, whilst focusing on the spiritual nature of the ritual, proto-transcendental experiences, mu-opioid receptor activation (measured via a pain proxy), and positive affect as potential driving mechanisms of social bonding during ritual.

It was found that, while there was a difference in level of proto-transcendental experience between the spiritual and secular yoga conditions, there was no difference in levels of social bonding between the spiritual and secular conditions. The finding that the spiritual versus secular nature of the ritual did not play a role in the level of social bonding is in line with previous field work comparing secular and non-secular rituals (Charles et al., 2021) as well as the hypotheses that it is the positive affect produced by behaviours, such as synchronous movement, within rituals that leads to social bonding (Dunbar, 2013), and not the religious or spiritual nature of a ritual.

However, proto-transcendental experience during the yoga did significantly predict level of social bonding.

The finding that proto-transcendental experience did significantly differ between the groups suggests that, while the secular versus spiritual nature of the ritual does not intrinsically lead to greater levels of social bonding, rituals that are more likely to promote a sense of awe, wonder or connection to something bigger than oneself (be they spiritual or secular) are those more likely to increase the sense of social bonding (see also Newson et al., 2021). In naturalistic settings, religious rituals are more likely than secular rituals to explicitly focus on transcendental experience (Van Cappellen, 2017). Therefore, the finding that proto-transcendental experience does predict level of social bonding within individuals, irrespective of ritual type, may reflect differences between the level of social bonding that takes place during *naturalistic* religious rituals compared to *naturalistic* secular rituals (but not behaviourally identical lab-based rituals). As such, this finding is in line with previous fieldwork research showing associations between social bonding and a connection to something bigger than oneself/transcendental experience (Charles et al., 2021), or a connection to a higher power (Charles, van Mulukom, et al., 2020; Pirutinsky et al., 2019).

The finding that proto-transcendental experience is related to an increased sense of social bonding could also be due to the two processes having a similar underlying cause. For example, it could be that both variables are different expressions of the same sense of ‘connection to something *outside* of oneself’, be it another person (i.e., social bonding) or something bigger (e.g. a deity, or the universe). Future work could study whether there is a distinction between social bonding and proto-transcendental experience or if they are, instead, the same effect manifested in a different way. Secular group gatherings that are able to create a sense of connection to something bigger than oneself/transcendental experience – such as sporting events that can allow one to feel connected to a team spirit (Halldorsson, 2020; Sullivan, 2018), or a music concert/festival that allows one to feel a connection to something sacred (Messick, 2019) – may be able to create social bonds in ways similar to religious rituals. Thus there is scope for future research to be conducted in these settings



to better understand ritual social bonding in secular contexts. The two-one-sided test (TOST) that we conducted provided evidence for there being no difference between the secular and spiritual version of the ritual, which suggests that, while the proto-transcendental experience different between the two types of ritual, this relationship was not enough, by itself, to cause a different in levels of social bonding. As the potential behavioural mechanisms underlying the social bonding that takes place during the rituals were designed to be the same, it could be that the behavioural mechanisms are more strongly related to feelings of social bonding than proto-transcendental experience.

Ritualistic behaviours are hypothesized to foster social bonding by bringing together, in an efficient way, a multitude of behaviours that each independently contribute to bonding (Dunbar, 2013, 2017; Machin & Dunbar, 2011). Examples of behaviours associated with social bonding that are included within rituals are shared attention (Wolf et al., 2016), shared goals (Reddish et al., 2013), synchronised movement (Launay et al., 2016; Tarr et al., 2016; Tarr et al., 2018) and music making (Freeman III, 1998; Kirschner & Tomasello, 2010; Kreutz, 2014; Tarr et al., 2015). Therefore, social bonding following yoga participation may also have followed from some of the behavioural mechanisms of yoga, such as joint attention, shared goals, and synchronised movement (Dunbar et al., 2016; Fischer & Kruekaew, 2020; Lang et al., 2017; Oesch, 2019; Tarr et al., 2016; Wilson & Gos, 2019; Wolf et al., 2016; Wolf & Tomasello, 2019, 2020b) as a result of engaging with the physical postures in a group context with shared attention on the person leading the yoga. One example of a potential mechanism is having shared mental states through joint attention (Haj-Mohamadi et al., 2018; Wolf & Tomasello, 2020a), and while it was outside of the scope of the current article, it would be interesting to combine the direct investigation of these mechanisms with the mechanisms examined in the current research.

In the current research we did examine two main biopsychological mechanisms thought to underlie social bonding in rituals, mu-opioids (Charles, Farias, et al., 2020) and positive affect (Fredrickson, 2013; Van Cappellen, Toth-Gauthier, et al., 2016). This study is the first to assess

both mechanisms in controlled conditions, using a longitudinal design. It was found that, when accounting for other possible variables, increases in positive affect significantly predicted increases in levels of social bonding with others, whereas no such effect for mu-opioids was found. This provides support for the Broaden and Build theory, which suggests that positive affect encourages broadening of behaviours and cognition that allows for social bonding to occur (Fredrickson, 2001, 2002, 2013).

Contrary to the hypothesis and previous work (Charles, van Mulukom, et al., 2020; 2012; Pearce et al., 2017), a significant role of the pain proxy for mu-opioids on social bonding was not found. One reason for not having found this effect could be that the role of mu-opioids on social bonding is not linear. Pellissier and colleagues (2018) have suggested there may be an inverted-U function for the role of opioids on social bonding, where there is an optimal level of opioids to encourage bonding, above or below which social bonding occurs less. Thus, using a proxy measure such as pain tolerance in a *linear* mixed-effects model would not be able to find this relationship. Alternatively, it might be argued that the relaxing nature/effect of yoga may lead to a lower level of opioids being released that might otherwise occur during group behaviour. However, we do not find such an argument compelling given past evidence of yoga directly leading to the release of mu-opioid ligands (Suri et al., 2017; Yadav et al., 2012)

Another, more plausible, reason for not having an effect of pain found where others have, is that a pain tolerance measure was used as the pain proxy for mu-opioid release, instead of pain threshold. Though some work that has provided evidence of a link between pain and social bonding have used pain tolerance (Johnson & Dunbar, 2016), the majority of this research has used pain threshold, instead of tolerance, as a proxy measure for mu-opioids (e.g. Charles, van Mulukom, et al., 2020; Cohen et al., 2010; Dunbar et al., 2016; Tarr et al., 2015; Weinstein et al., 2016). While pain tolerance and threshold are correlated with one another (Bhalang et al., 2005), pain tolerance and threshold have been shown to be distinct sub-domains of pain perception (Gelfand, 1964; Lacourt et al., 2012; Vaegter et al., 2017). As such, it likely that pain threshold should be used to as

a proxy for mu-opioid activation instead of pain tolerance in future research (for further information on a link between mu-opioids and pain threshold, but not tolerance, see Fillingim et al., 2005; Hagelberg et al., 2012; Huang et al., 2008; Kialka et al., 2016).

A methodological limitation of this study was the wording of the question regarding proto-transcendental experience (“During today’s meeting, did you feel connected to something bigger than yourself, like the universe, and/or feel a sense of awe or wonder?”). Initially, this was conceived of as a secular analogue for “a feeling of connection to God, Jesus, and/or the Holy Spirit”, which has previously been reported as a significant predictor of social bonding (Charles, van Mulukom, et al., 2020). However, we understand that the wording of this analogue is double-barrelled in that it asks about a connection to something bigger *and* about a feeling of awe in a single question. However, we do not believe this issue to be too great: self-transcendence in secular settings is often construed as awe (Chirico & Yaden, 2018; Van Cappellen, 2017), and currently unpublished data we have from a separate study suggests that this question significantly correlates with self-transcendent awe ( $r = .64$ ), specifically the vastness ( $r = .69$ ) and connectedness ( $r = .69$ ) sub-constructs of the AWE-S scale (Yaden et al., 2017). So, we argue that for the present purpose the two parts to the questions target the same psychological construct we aimed to examine (i.e., the experience of self-transcendence during a ritual, whether religious/spiritual or secular).

Another limitation of this study is that the analysis used (multi-level modelling) was not the one planned in the pre-registration of this article. This is because we later found that the pre-registration for the study did not have a suitable type of analysis for the data collected. Another limitation is that, while a previously existing, realistic ritual that has both a secular and spiritual form (i.e., yoga) was used, it is possible that one of the reasons an effect of ritual type was not found is that participants who took part in the spiritual form of yoga may not have felt that the spiritual yoga reflected their own beliefs, unlike naturalistic religious/spiritual rituals would do (though note that most participants in both groups did report that the yoga sessions had felt meaningful to them when asked after the final session, suggesting that this may not have been a key

reason). Future research on ritual social bonding could directly examine the role of mu-opioids in rituals in a controlled setting, either via neuroimaging-tracer methods (e.g. Ashok et al., 2019; Karjalainen et al., 2019; Nummenmaa et al., 2020) or using pharmacological opioid antagonists (e.g. Charles, Farias, et al., 2020; Inagaki et al., 2019a, 2019b; Tarr et al., 2017). Finally, a further avenue for future research would be to look explicitly at the role of positive affect, mu-opioids and social bonding on health and wellbeing outcomes in those that take part in rituals, to assist our understanding of the connection between religion and health (VanderWeele, 2017).

In summary, here we present the first study to assess differences in social bonding between spiritual and secular ritual in controlled conditions, using a longitudinal design. It was found that while there was no difference in social bonding between the spiritual and secular yoga group, positive affect plays a significant role in social bonding, as does a proto-transcendental experience (e.g., feeling connected to something bigger than oneself) during the ritual. This supports the Broaden and Build hypothesis (Fredrickson, 2013), but not the mu-opioid theory of social bonding (Machin & Dunbar, 2011).

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