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Author for correspondence:
Ronald Fischer
e-mail: ronald.fischer@vuw.ac.nz

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Time investments in rituals are associated with social bonding, affect and subjective health: a longitudinal study of Diwali in two Indian communities

Purnima Singh[1], Shruti Tewari[2], Rebekka Kesberg[3], Johannes Alfons Karl[4], Joseph Bulbulia[5] and Ronald Fischer[4,6]

[1]Department of Humanities and Social Sciences, Indian Institute of Technology Delhi, New Delhi 110016, India
[2]Humanities and Social Sciences, Indian Institute of Management, Indore, India
[3]Fakultät für Ingenieurswissenschaften, Informatik und Psychologie, Abteilung Sozialpsychologie, Universität Ulm, Ulm, Germany
[4]School of Psychology, Victoria University of Wellington, Wellington, New Zealand
[5]School of Humanities, Faculty of Arts, Auckland University, Auckland, New Zealand
[6]Institute D'Or de Pesquisa e Ensino, Sao Paulo, Brazil

ST, 0000-0003-1903-7252; RK, 0000-0002-2240-2401; JAK, 0000-0001-5166-0728; RF, 0000-0002-3055-3955

Rituals are performed within specific socio-ecological niches, yet the different effects of the same ritual form across different niches (community contexts) remains unclear. Here, using longitudinal measures over a two-week period during Diwali (the Indian festival of light), we investigate the relationship between ritual time allocation and social cohesion in two Indian communities. First, the positive effects of ritual on social bonding, perceived health and affect were highest on the focal day of the festival. Second, we observed anticipatory effects of ritualistic commitment on affect prior to the main day of the festival. Third, social bonding patterns were similar in the two Indian settings, indicating that Diwali fosters social cohesion across diverse social ecologies (cultural niches). However, individually focused emotional benefits appear to dampened in more cosmopolitan environments. Finally, time investments reveal diminishing marginal utilities for ritual activities on social cognition. Ritual time investments were linked to greater affect and family cohesion up to a certain limit. We argue that attention to the diminishing returns of ritual time investments on social cohesion across diverse human ecologies is an important horizon for future cross-cultural investigations.

This article is part of the theme issue 'Ritual renaissance: new insights into the most human of behaviours'.

1. Introduction

Recent research on collective rituals has focusing on dysphoric rituals involving pain, ordeal and negative affect, with increasing evidence emerging that increased ordeal increases social cohesion [1–3]. Less is known about the effects of rituals involving little or no physical ordeal and neutral or positive emotional valence [4]. At the same time, even rituals that are neither arousing or physically demanding typically still involve substantial time and resource allocations. Are these costs investments, and if so, who benefits, and how? Previous studies have shown that increased cost (e.g. time or energy invested) is related to increased social cohesion and higher group status of individuals [5,6]. Signalling theory posits that hard-to-fake signals of group commitment help to solve collective action problems threatened by defection [5,7–12]. We propose that one functionally effective signal of cooperative attachment is time commitment because time is a limited resource [13,14]. Applied to the study of rituals, in which ritual attendance is not coerced, and where people may select how

much time they want to invest in preparation and participation, time investments might be a good indicator of the importance people attribute to group membership. Additionally, large-scale coordination problems may be threatened by risk [15]. For risky coordination problems, rituals may support collective action by expressing cooperative sentiments automatically—what researchers have called 'charismatic' signalling [8,16]. Both classical signalling theories and charismatic signalling theories predict that greater time-allocations to religious activities will be associated with greater prosocial responses.

To date, relatively little work has examined how time commitments to ritual relate to psychological outcomes, including social cohesion, affective processes and subjective health ratings [17].

As noted by a number of authors [18–24], rituals may have possible effects beyond social cohesion: participation in ritual is associated with perceived health benefits in different communities, even when the activities involved substantial levels of discomfort and physical ordeal [24,25]. However, the direction of any health or emotional effects may follow divergent patterns [26], requiring greater attention to the overall profile of any ritualistic effects before, during and after a ritual. We, therefore, examine whether emotional processes (affect) and subjective health ratings are primarily increased on days when a community celebrates a community ritual. Similar to social cohesion described above, we also examine the associations with reported time that individuals engaged each day in activities directly relevant for the festival. Affect might be more positive on days of ritualistic activity (see [21]), but can this be linked to the time spent on ritualistic activities? We ask: to what extent does engaging in activities related to the ritual lead to better (or worse) wellbeing and positive affect?

To separate the effects of ritual-specific activities from more generic religious commitment, we differentiated ritual-specific effects from commitment to general religious activities, such as time spent praying or performing religious activities that are not directly associated with the focal ritual. This allows us to more clearly separate focused ritualistic activity from non-ritual religious behaviour. We examine both linear and nonlinear effects because it is questionable whether time commitments can be extended infinitely given the biological time constraints of sleep–wake cycles. Importantly, this approach allows us to identify whether there is a locally optimal level of time commitment [27]: e.g. are there diminishing returns of ritualistic commitment on psychologically relevant outcomes?

The effect of any ritualistic activity may also depend on the socio-ecological niche or location within which the ritual is being conducted. Previous studies (e.g. [24,25,28–30]) have focused on more traditional communities in order to understand how ritualistic behaviour affects individuals and communities, allowing some insights into the possible evolutionary mechanisms that led to the emergence and maintenance of rituals in human societies. Rituals emerged in specific social niches, possibly in response to specific ecological or social demands (for a broader perspective on niches in evolutionary biology, see [31]). In the contemporary global environment, traditional rituals are being performed in diverse settings, including by communities whose life has been significantly transformed by economic and social development. The celebration of rituals across communities opens up important questions about the functioning of collective ritual within and across different social niches, and may allow some further insights regarding by-product and adaptationist theories about ritual. We study the effects of collective ritual in one of the holiest places in India (Prayagraj) and the metropolitan and administrative centre of the country (Delhi). Both places have important spiritual and historical significance. Prayagraj is translated as the 'place of sacrifice or offering', which lies near the confluences of the three sacred rivers in Hinduism (Triveni Sangam) and is the main site of the Khumb Mela, one of the largest religious pilgrimages in the world. Delhi is historically the administrative centre of the subcontinent and has various places of spiritual importance. At the same time, because of being the administrative and economic centre of the country as well as attracting a large number of internal migrants, it is considerably more metropolitan and cosmopolitan. By comparing these two sites and the relative temporal and time commitment effects, we will be able to address some broader questions about evolutionary dynamics of ritual.

Specifically, one of the central arguments about the evolutionary functionality of rituals has been that rituals performed in social groups increase social bonding, explaining their persistence over human history despite their costs and putting adaptive functions at the level of the group (e.g. [19,32–34]). We examine the effects of time commitment as one possible social signal on social bonding responses in two sites that vary in terms of religious importance.

Greater time commitment should be associated with greater social cohesion, independent of the geographical location sampled. However, as noted above, ritual has also been shown to affect emotional processes (e.g. [19]), which may indicate further adaptive functions of ritual for both individuals and communities. Increases in positive affect and perceived health *independent* of time commitments in both locations may suggest that rituals evoke pleasure without additional functional benefits for the group. This pattern would be compatible with both adaptive and by-product theories of ritual. By contrast, if affective reactions are conditional on time commitments, this would suggest that there are adaptive functions for individuals, most likely in the form of emotion regulation through extended engagement with ritualistic activities (see [26]). Finally, if there are positive effects on all our main outcome variables in the more traditional religious context, but no or even negative effects of rituals in the relatively more cosmopolitan context, this would point towards negative niche-construction dynamics [31], in which ritual effects are conditional on dynamics at the individual, group and environmental level.

In summary, the aim of the current project was to (i) investigate the relationship between time commitment and social bonding, (ii) investigate temporal ritual and time commitment effects on subjective health and affective processes, and (iii) investigate niche effects of rituals. Through a temporal analysis of affective processes vis-à-vis group connectedness and time commitment in two settings that vary in their spiritual and religious importance, we can shed new light on possible underlying functions of ritual.

(a) The research context

We focused on Diwali (Deepawali), the Indian festival of light. It marks the victory of light over darkness and good over evil. In the Indian context, Diwali is a 5-day celebration. The festival starts with a number of preparatory steps, including cleaning and decorating the house and workplace, shopping for new

clothes, gold, silver jewellery or kitchen utensils for good luck as well as giving as gifts to family members and friends, and preparing delicacies for visitors. These activities are typically done collectively: the family members together would clean, decorate and cook (if the financial situation allows it, with the help of domestic helpers). Information about new gift options, best prices and quality are also shared through social networks and interaction with family and friends. On the main day of the festival, people visit their friends and relatives and offer a special puja (prayer) to the goddess of prosperity and wealth (Lakshmi). The festivities on this day include lavish meals, with a special variety of sweets and firework displays. The festival is the most important religious festival in modern India and is widely performed by Indian communities around the world. Hence, it is one of the most widely celebrated rituals in the world today and provides an interesting case study for examining ritualistic effects. We focus on time commitments to various activities relevant for preparing and performing Diwali.

2. Material and methods

(a) Sample and procedure

We recruited Indian nationals prior to the festival via personal contacts and quasi-random recruitment in the week leading up to Diwali. Individuals were approached by field investigators at their residences and invited to participate. The first survey was done as a face-to-face interview after written consent was given. Field investigators visited residences on the consecutive days to collect the data, either via interview or the response survey was completed by participants in their own time. The second survey was conducted 2 days prior to Diwali, followed by data collected on the day of Diwali, 2 days after Diwali and the final collection took place one week after. The sample consisted of 486 participants (females = 258, males = 226, others = 2; mean age 30.9 years), with 271 sampled in Prayagraj and 215 individuals residing in Delhi. Prayagraj is a more conservative and traditional location in which individuals are still performing Diwali rituals in more traditional family settings. Delhi in contrast is a metropolitan city in which the rituals have been adapted to fit routines in a large urban environment and require substantive amount of travel and expenses to perform the family focused activities.

(b) Instruments

Perceived health and symptoms were adapted from Tewari *et al.* [24]. The three-item wellbeing scale was originally from the core module of the Centers for Disease Control and Prevention Health Related Quality of Life Measure (CDC HRQOL-14). Mental and physical health symptoms were specifically developed for the Indian subcontinent by Tewari *et al.* [24]. All items were measured on a five-point response scale and higher scores indicated greater wellbeing and more health symptoms (lack of wellbeing). The psychometric properties for health are reported in the electronic supplementary material.

(i) Affect

We used an adapted version of the Positive Negative Affect Scale (PANAS, [35]) with three positive mood items and two negative mood items. We also used a more ritual relevant emotional experience scale developed by Zentner *et al.* [36], which measured feelings of wonder and amazement, transcendence and experience of the sublime and experiences of bliss. We labelled this scale 'awe'. All items were scored on a seven-point Likert scale anchored by 'not at all' to 'completely'. See the electronic supplementary material for further information on the psychometric properties.

(ii) Social bonding

We used the inclusion of self in others [37] and the Harb & Smith [38] social connectedness measure to measure social bonding with (i) family and (ii) Hindus. This helps to differentiate proximal and distal group social bonding processes. The average correlation between the inclusion of self in others measure and social connectedness with family averaging across all time points was 0.50 (min = 0.37; max = 0.69). The average correlation for the two measures with the focus on Hindus was 0.48 (min = 0.35; max = 0.71). Therefore, we averaged the inclusion of self in others and social connectedness items for family and Hindus, respectively.

(iii) Time commitment

We coded time commitment to religious activities in general as well as Diwali-related activities specifically. Individuals indicated how much time (coded in minutes, see the electronic supplementary material for descriptive information) they spent each day on cleaning the house, decorating their home, preparing delicacies, buying gifts for friends and family, shopping for puja related activities and visiting friends and family (Diwali-related activities). We used general religious activities (praying at home, going to the temple and preparing for puja) as a control and comparison category. All raw activities were summed within categories.

(iv) Demographic variables

We adjusted for age, gender, marital status (married versus not married), caste (general class versus scheduled caste and other backward class), education (illiterate; primary; high school; graduate; post-graduate and above), self-reported socio-economic status (lower; lower middle; upper middle; upper; [39,40]) and socio-economic status derived from household possessions and appliances ([41]; sum score of number of devices and services available in the household of the participant).

3. Results

(a) Temporal dynamics

In order to examine the effects of ritual on social bonding, affective responses and perceived health, we first estimated unconditional growth models with time as a predictor. We tested for linear and quadratic time trends. For all dependent variables the intercept represents the mean value of the outcome at Diwali, the main day of the ritual. The time coefficients represent the expected change in the dependent variables if the predictor is changed by one unit (day as measurement point). Random effects represent individual deviances from the mean intercepts or mean slopes. There were linear temporal effects on positive affect, awe, family cohesion and a trend for symptoms. However, the presence of quadratic effects for these variables (except positive affect) as well as for health and connectedness with Hindus suggested that psychological responses are time dependent. Ratings of subjective health,

Table 1. Unconditional growth model examining temporal effects (day) on health, affect and social bonding. ($n = 425$, number of observations = 2065. Numbers in brackets show standard errors for fixed effects and standard deviation for random effects. ***$p < 0.001$; **$p < 0.01$; *$p < 0.05$; $^{\#}p < 0.10$.)

	health	symptoms	positive affect	awe	Hindu	family
fixed effects						
intercept	3.82*** (0.02)	1.58*** (0.02)	5.20*** (0.03)	2.80*** (0.05)	4.89*** (0.06)	6.14*** (0.04)
time	0.00 (0.01)	−0.02$^{\#}$ (0.01)	0.03* (0.01)	−0.06*** (0.02)	0.00 (0.01)	−0.02* (0.01)
time^2	−3.86*** (0.65)	2.93*** (0.59)	1.17 (0.87)	−2.13$^{\#}$ (1.15)	−3.00*** (0.87)	−2.31** (0.72)
random effects						
intercept	0.20 (0.45)	0.20 (0.45)	0.43 (0.66)	0.94 (0.97)	1.45 (1.21)	0.83 (0.91)
residual	0.42 (0.65)	0.33 (0.58)	1.18 (1.09)	1.29 (1.14)	0.74 (0.86)	0.50 (0.71)

and connectedness with both Hindus and family peaked on the day of the ritual; whereas health symptoms were lowest on the main day of the ritual. These effects held when controlling for demographic background variables (see the electronic supplementary material). The overall pattern of day-specific effects for both affective and social cohesion variables points towards an adaptive function of ritual at both individual and group level (table 1 and figure 1).

(b) Time spent on Diwali activities

We next explored the effects of time that individuals reported spending on specific Diwali-related activities on our outcome variables. The overall pattern suggested that engaging in Diwali activities was associated with more self-reported health and awe, but the negative quadratic effects implied that these effects levelled off above a threshold of about 500 min per day (approx. 8 + h). For connectedness with other Hindus and family, more time spent on Diwali-related activities was associated with positive increases. There was also a trend for diminishing returns of Diwali commitment on family connectedness ($p = 0.05$). Overall, the patterns support signalling theories of ritual time-investment, but also suggest that time commitment to the ritual exhibits diminishing marginal utilities, with decreasing returns of behavioural investments for positive affective and health (table 2 and figure 2).

These effects might be conditional on the day of the festival—it should matter how much time is spent on Diwali-related activities either on the main day of Diwali or before, but not so much after the festival. Therefore, we examined the interdependent effects of temporal structure of the ritual itself and time commitment to the ritual. First of all, the temporal structure effects of Diwali on health, symptoms, awe and family connectedness remained—people felt better about themselves, felt more awe and were more connected to their families on Diwali itself compared to before or after. We also found a statistically significant interaction between time commitment to Diwali activities and a quadratic time (day) effect. For positive affect and awe, engaging in Diwali-related activities before or after the ritual was associated with more positive affect and more experiences of awe ($p < 0.05$), whereas on the day itself spending more time on relevant activities was not statistically significantly associated with positive affect ($p > 0.10$) and was statistically significant ($p < 0.05$) but considerably less strong for awe (table 3 and figure 3).

We also found an interaction between the curvilinear time and curvilinear commitment effects for family connectedness—on the day of Diwali itself, the more time people spent on Diwali-related activities, the more they felt connected. This effect also held on the measurement point after Diwali. However, prior to Diwali and one week after Diwali there was an optimal level of time commitment that led to high family connectedness (between 250 and 500 min per day), above which the connectedness to one's family rapidly decreased. In other words, ritualistic activities on the day of the ritual has positive effects on family connectedness, but before or after the festival there is an optimal level above which effects deteriorate. Overall, these observations are consistent with predictions from signalling theories, but imply that signals are time-bound. It also suggests that it is not just socializing with family and performing goal-directed activities together *per se* that is functionally important, but that there is an added effect of committing time on specific dates that are ritually important.

Here, we investigate Diwali-related activities, but it is important to examine to what extent these effects are specific to activities associated with this ritual or whether they reflect religious commitment effects overall, independent of the specific ritual. We, therefore, re-ran all the analyses adjusting for religious time commitments. The effects reported above for health, affective processes and social connectedness remained in the same directions and statistically significant when controlling for religious commitment. The temporal structure effect on social connectedness with Hindus remained in the same direction, but was not statistically significant. See the electronic supplementary material for the full results.

(c) Niche specific effects

In the previous section, we reported both temporal and commitment effects in the combined sample. However, we sampled participants in two different niches varying in spiritual importance. Concerning the main effect of location on our dependent variables, connectedness with other Hindus and with one's family were higher in the more traditional context; whereas positive affect and feelings of awe over all time points were higher in Delhi.

We next examined whether any of the temporal or time commitment effects varied by niche. Because the location analyses are exploratory, we adjusted the significance levels by the number of interaction tests that we conducted (effective significance level: $p < 0.0007$). Overall, participants in Delhi

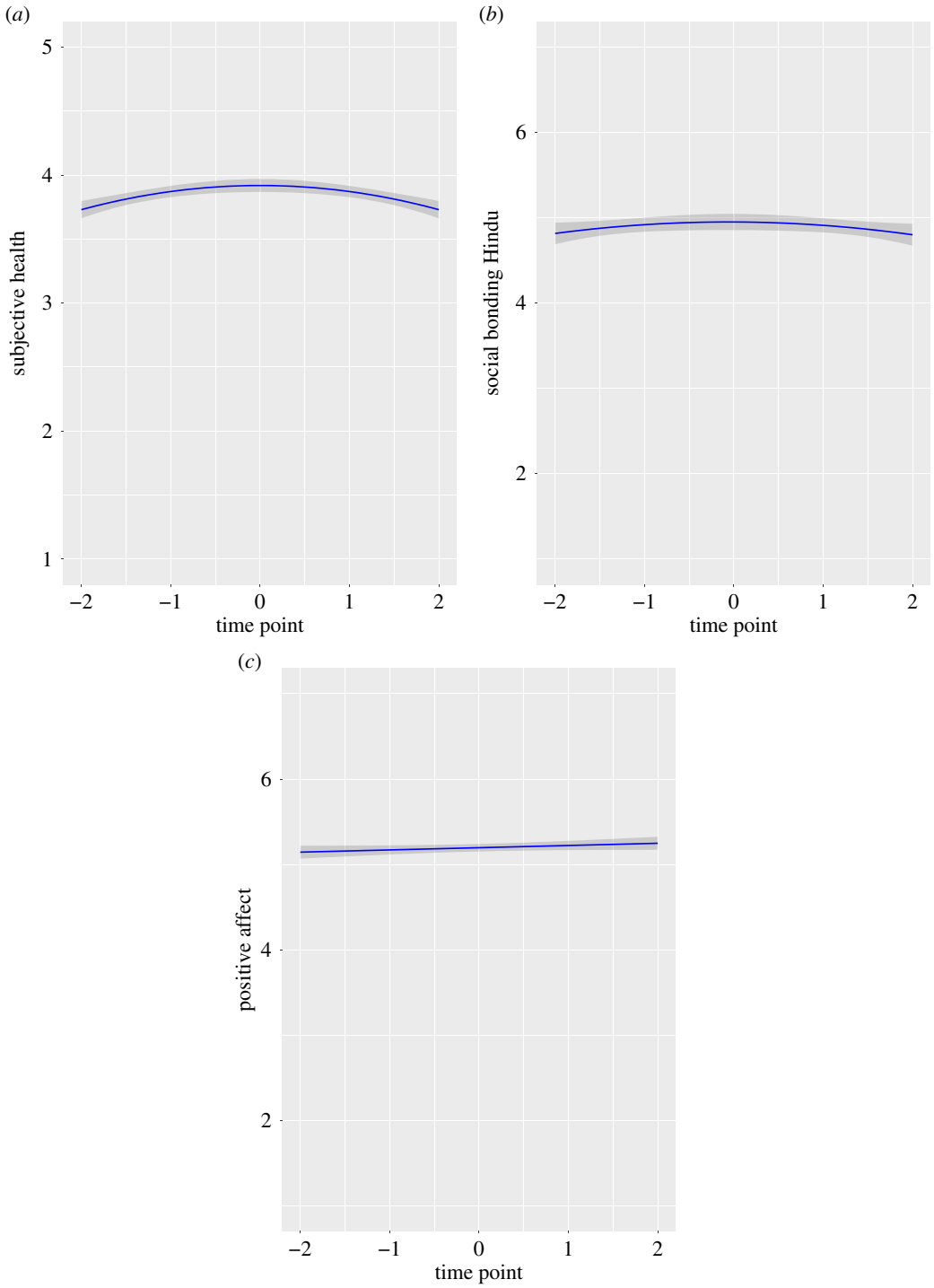

Figure 1. Ritualistic effects on (*a*) perceived health and (*b*) social bonding are highest on the focal day of the festival, but steadily increasing for (*c*) positive affect. Note: time is coded as −2 (one week before festival), −1 (2 days before the main festival day), 0 (main day of Diwali), 1 (2 days after the main day), 2 (one week after). (Online version in colour.)

reported spending more time on Diwali. Comparing the specific activities, the overall difference in time commitment between locations seems to be driven by shopping and visiting family and friends, which, in turn, may be owing to the larger distances and greater travel volume (e.g. traffic jams) in Delhi compared to Prayagraj. Focusing on the temporal structure effects first, there were location by time effects for symptoms, positive affect and awe. In Prayagraj, awe was higher and health symptoms were significantly lower on the day of Diwali compared to before or after (all comparisons $p_{\text{adjusted}} < 0.05$). In Delhi, the reported level of awe and symptoms did not vary by day. However, positive affect was reliably lower on the day of Diwali in Delhi compared to before or after, but no such effect was evident in Prayagraj. These patterns suggest that ritualistic effects on health and emotional processes are stronger in a more traditional context compared to a more cosmopolitan context (figure 4).

Examining location difference for time commitment, the only effect that survived after adjusting for multiple tests was for awe. In Prayagraj, more time spent on Diwali-related activities was associated with an overall increase in feelings of awe. No statistically significant effect was found in Delhi. When testing all the effects by location in the same model, only the temporal effects on positive affect and awe were reliably different between the two contexts. Similar to the patterns reported before for health and social bonding, positive

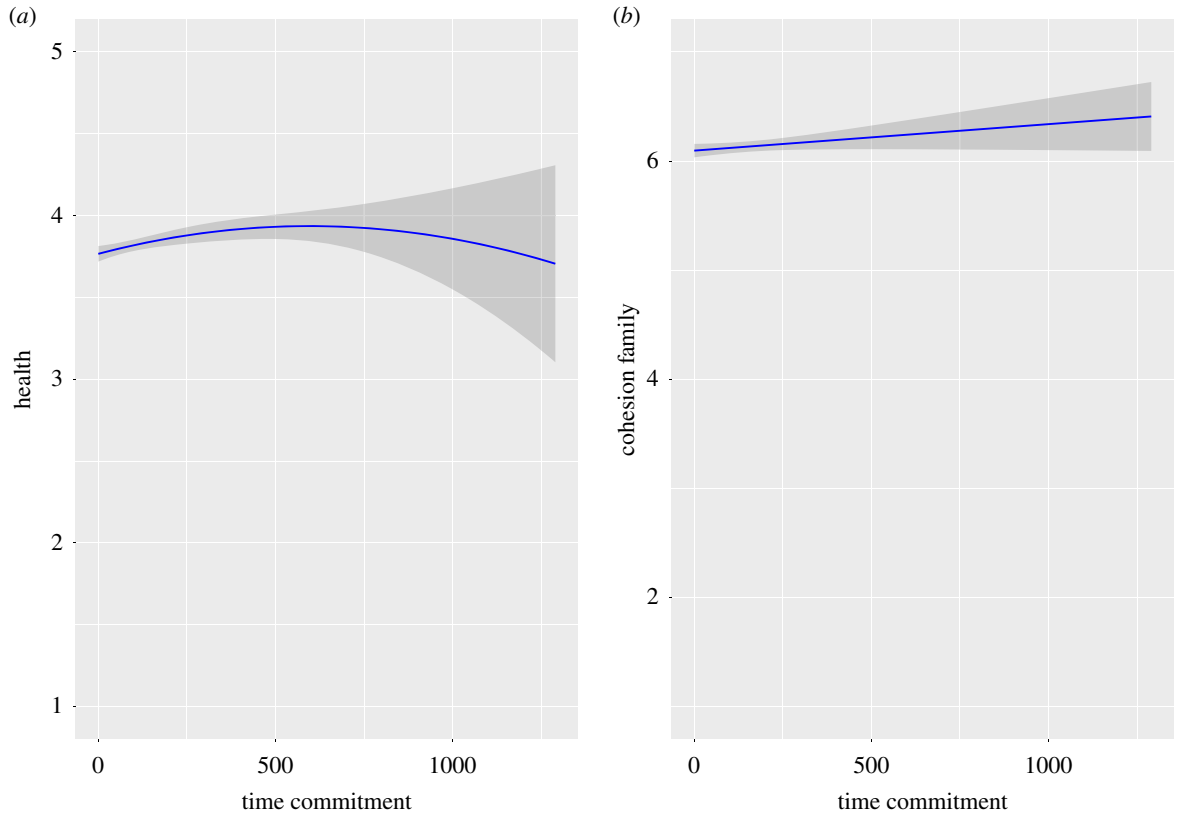

Figure 2. Increases in Diwali commitment is associated with (*a*) diminishing returns for perceived health and (*b*) increases in social bonding with family. Note: time commitment to Diwali activities is coded as minutes per day. (Online version in colour.)

Table 2. Multi-level model examining time commitment effects on health, affect and social bonding. ($n = 425$, number of observations = 2065. Numbers in brackets show standard errors for fixed effects and standard deviation for random effects. ***$p < 0.001$; **$p < 0.01$; *$p < 0.05$; $^{\#}p < 0.10$.)

	health	symptoms	positive affect	awe	Hindu	family
fixed effects						
intercept	3.76*** (0.03)	1.59*** (0.03)	5.18*** (0.04)	2.72*** (0.05)	4.83*** (0.06)	6.10*** (0.05)
Diwali	0.00*** (0.00)	−0.00 (0.00)	0.00 (0.00)	0.00*** (0.00)	0.00*** (0.00)	0.00* (0.00)
Diwali^2	−1.86* (0.74)	0.27 (0.68)	−2.55** (0.99)	−6.29*** (1.32)	−1.22 (1.03)	−1.61$^{\#}$ (0.85)
random effects						
intercept	0.21 (0.45)	0.20 (0.45)	0.41 (0.64)	0.89 (0.94)	1.44 (1.20)	0.83 (0.91)
residual	0.42 (0.65)	0.34 (0.59)	0.74 (0.86)	1.29 (1.14)	0.74 (0.86)	0.50 (0.71)

affect was reliably lower in Delhi on the day of Diwali; whereas awe was reliably higher on the day of Diwali in Prayagraj. No divergent effects on health or social connectedness by location were found.

4. Discussion

Here, we present findings from a longitudinal study of human ritual behaviour across two natural human ecologies, where we investigated magnitudes of social and affective change over the course of this multi-day ritual. Our theoretical focus is on how time investments affect dimensions of social and emotional cognition.

(i) *We found a positive effect of ritual behaviour on emotion, health and social bonding, which peaks on the focal day of the ritual compared to before and after*. This finding suggests that rituals have beneficial effects both for individuals and communities. Looking ahead, future research could examine whether similar effects can also be observed for other social rituals. Given the hypersocial nature of the human species, we would expect that voluntary gatherings which require some level of preparation and effort by participants are experienced as positive and contribute to feelings of social bonding on the days where those events are taking place. It might be particularly interesting to compare events that require some ritualistic preparation from social gatherings more broadly which require little or no prior preparation. We speculate that events that involve explicit 'ritualization' [42] compared to generic social events invoke stronger social bonding responses.

(ii) *We find that time invested in the ritual affects social and affective cognition*. This indicates that ritual effects are at least

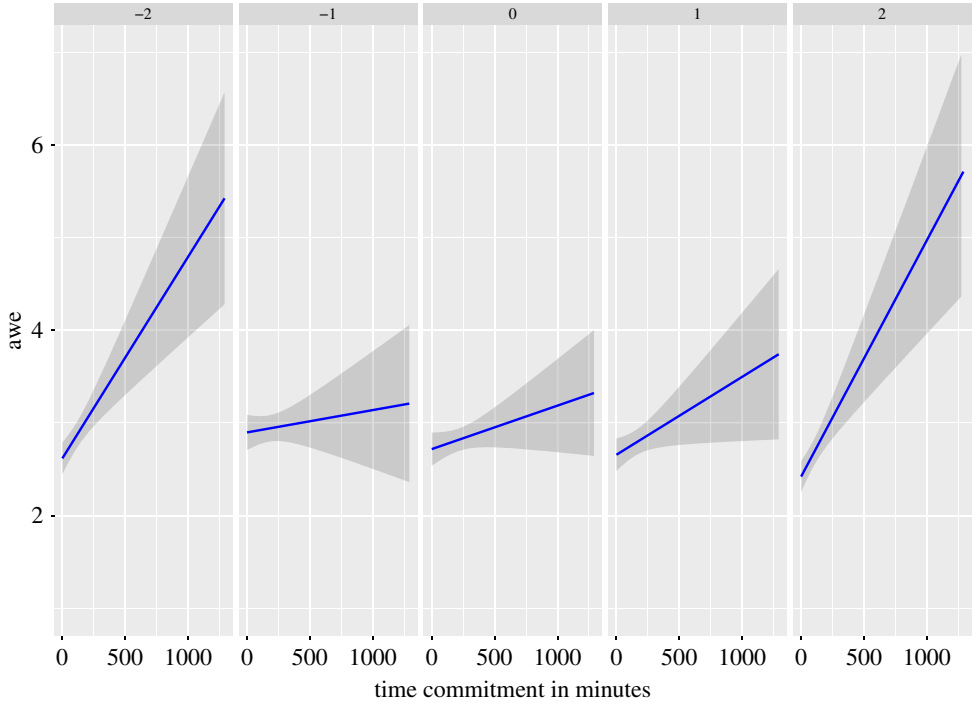

Figure 3. Interaction of time commitment on awe by day of measurement. Note: effects are significantly stronger with greater time spent on preparation one week before the festival compared to during the festival. Time is coded as −2 (one week before festival), −1 (2 days before the main festival day), 0 (main day of Diwali), 1 (2 days after the main day), 2 (one week after). The time commitment to Diwali activities is coded as minutes per day. (Online version in colour.)

Table 3. Interdependent effects between the day of the ritual and time commitments to the ritual on health, affect and social bonding. ($n = 425$, number of observations = 2065. Numbers in brackets show standard errors for fixed effects and standard deviation for random effects. Adjusting for the number of tests conducted (that is 48) all effects below $p \leq 0.001$ (indicated by ***) remain significant. ***$p < 0.001$; **$p < 0.01$; *$p < 0.05$; $^{\#}p < 0.10$.)

	health	symptoms	positive affect	awe	Hindu	family
fixed effects						
intercept	3.78*** (0.03)	1.57*** (0.03)	5.17*** (0.04)	2.72*** (0.06)	4.85*** (0.06)	6.12*** (0.05)
time	0.00 (0.01)	−0.01 (0.01)	0.02 (0.02)	−0.05* (0.02)	0.01 (0.02)	−0.02 (0.01)
time^2	−2.56** (0.90)	2.66** (0.81)	−0.41 (1.19)	−3.58* (1.58)	−1.56 (1.21)	−2.31* (0.99)
Diwali	0.00** (0.00)	0.00 (0.00)	0.00* (0.00)	0.00*** (0.00)	0.00$^{\#}$ (0.00)	0.00 (0.00)
Diwali^2	−1.27 (0.81)	−0.53 (0.74)	−2.80** (1.08)	−4.97*** (1.44)	−1.62 (1.13)	−1.45 (0.93)
time × Diwali	0.00 (0.00)	−0.00 (0.00)	0.00 (0.00)	−0.00 (0.00)	−0.00 (0.00)	−0.00 (0.00)
time × Diwali^2	0.31 (0.58)	−0.61 (0.52)	−0.69 (0.77)	1.44 (1.02)	−1.07 (0.79)	0.02 (0.64)
time^2 × Diwali	−0.00 (0.00)	−0.00 (0.00)	0.02** (0.01)	0.02** (0.01)	−0.01 (0.01)	0.00 (0.01)
time^2 × Diwali^2	19.55 (36.25)	−47.53 (32.92)	−85.99 (48.37)	98.18 (64.24)	−90.16$^{\#}$ (49.49)	−115.70** (40.60)
random effects						
intercept	0.20 (0.45)	0.20 (0.45)	0.42 (0.65)	0.89 (1.28)	1.45 (1.20)	0.82 (0.91)
residual	0.41 (0.64)	0.34 (0.58)	0.73 (0.86)	0.94 (1.13)	0.74 (0.86)	0.50 (0.71)

partially driven via time spent in preparing for the ritual. Given the social nature of the preparation, we argue that time commitments may function as indices of commitment to the larger ethno-religious group that is performing this ritual. The interaction of time commitments with timing of the ritual also suggests that these time commitment effects are not just a side-effect of getting together and engaging in goal-directed behaviours, but that performing these activities on a specific day is associated with added benefits that are not evident when engaging in the same activities on other days.

Importantly for broader theorizing, we found that time commitment effects exhibit properties of diminishing marginal utilities. Extending commitment to a specific ritual is not an unlimited resource for humans with a relative fixed wake–sleep cycle, hence time investments as a social signal might be functional up to an optimum that balances biological demands with social utility.

Looking ahead, it is important to note that although time allocation is one dimension of ritual investment, it is not the only indicator, and perhaps not the most

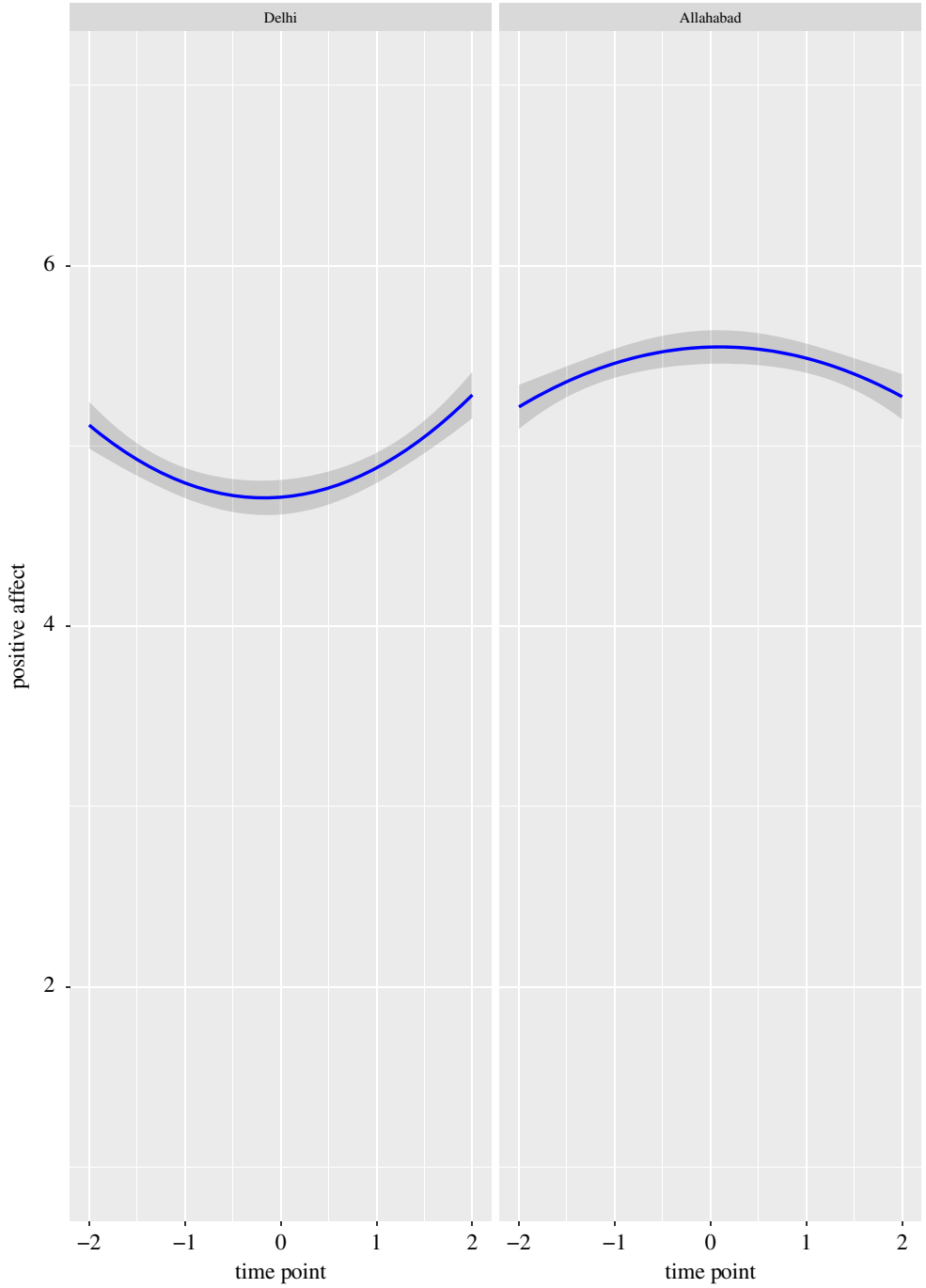

Figure 4. Location-specific effects of time of festival on positive affect, showing lower positive affect in the less traditional context (Delhi, left panel) compared to a more traditional context (Prayagraj, right panel). Note: curvilinear effect in Prayagraj is not statistically reliable. Time is coded as −2 (one week before festival), −1 (2 days before the main festival day), 0 (main day of Diwali), 1 (2 days after the main day), 2 (one week after). (Online version in colour.)

relevant to assessing signalling models of ritual in general. For example, monetary donations, number of people hosted for ritualistic activities or public display of devotion via piercings or other visible and objectively verifiable behaviours (e.g. [29]) may provide more direct tests of signalling models. Furthermore, the patterns observed here raise the question of whether other behavioural signals show similar diminishing marginal utility effects or is time a specific limited resource that differs from other behavioural signals? Future research comparing different types of signals is needed.

(iii) *We find potential anticipation effects for positive affect and perceived awe, with increased positive affect and awe with greater commitment to ritualist preparation activities arising in the period leading up to the main event, but no direct relationship between time expenditure and emotional responses on the focal day.* The anticipatory affect model [43] proposes that all future outcomes vary in terms of uncertainty and valence, with levels of uncertainty increasing arousal, and anticipated gains versus loss affecting valence. This anticipatory affect is thought to be evolutionarily adaptive in that it promotes either approach or avoidance behaviour. Applying these principles to ritual, the anticipation of positive outcomes of collective ritual (e.g. social connection with loved ones) appears to create positive affect in anticipation, which then may feed back into increasing motivation to engage in preparatory actions towards the ritual. Hence, anticipatory affect may contribute to the

adaptive social function of ritual, in that it promotes energy spent towards preparation for the ritual, which in turn leads to more social bonding. This reasoning is in line with our overall pattern: time spent on activity was stronger for affect prior to the focal day of the ritual. These patterns suggest that emotional processes can reinforce social outcomes of ritual.

(iv) *Concerning niche effects, we did not find location differences for social cohesion responses, which points towards continuing group-level benefits of ritual even in more individualistic, cosmopolitan and less traditional conditions.* Supporting functional theories of ritual, group-level benefits of ritual may continue even to the extent that larger impersonal communities who partake of the same ritual remain largely anonymous from each other. The main niche differences we found were related to the temporal sequences, especially related to affective responses. In a cosmopolitan context, the affective benefits of the ritual seem to have diminished compared to the pattern observed in a more traditionally religious context. One possible explanation could be owing to the perceived costs involved in practising the ritual in a highly urban environment, in which family is dispersed, requiring more travel in highly congested and polluted urban spaces, and gift giving may take on a more secular economic exchange function [44,45]. These perceived costs (time, money, energy invested) appear to increase uncertainty and decrease expectations of gains, thereby decreasing the cost-benefit ratio and associated positive experiences of the ritual. Hence, affective reactions may diminish when rituals are performed in settings that are not aligned with the original niche conditions in which the ritual was initially performed.

Looking ahead, previous studies on rituals have focused on the evolutionary benefits of rituals, either at the individual or group level, without considering specific niche conditions. The socio-ecological niches within which a particular ritual evolved compared to how a ritual may be performed in today's environment is an important dimension to be examined. Our patterns suggest that group-level benefits persist, but that individual level affective experiences of ritual may shift in changing socio-ecological niches.

(a) Limitations

Our study is limited in several ways. First, our measures were based on self-reports and did not include co-participants or targets of the ritual activities (e.g. were these activities performed with family members only or were other people involved). Future studies with observational, behavioural or physiological measures could test the validity of these patterns beyond self-reports and map the social dynamics and networks more directly. Second, it would be useful to extend these analyses to other ritualistic contexts to examine whether social gatherings as part of a ritual alone are sufficient for producing positive effects or whether time commitment is essential for reaping the benefits at both an individual and group level. The reported activities (e.g. shopping, cooking) are important for, and a substantial part of the Diwali celebration, yet people also perform these activities on other days throughout the rest of the year. Therefore, to distinguish the specific effects of the activity related to the ritual and the effect of the activity itself, a future study could examine the activity in different contexts (e.g. cooking for the family versus cooking for a sports event).

Third, future studies should explore the possibility of including active control conditions or extending the window of observation to include intervals that are well outside the focal ritual setting as well as moving beyond pure correlational designs. We used a within-group design to overcome noted problems with between-group studies (e.g. control group designs) when studying effects in real-world settings (e.g. [46,47]). Within-group effects have the advantage of treating each participant as her/his own baseline. We were able to test the strength of association of having reported more time spent on a specific activity with key variables of interest (e.g. social bonding, emotional states). It overcomes the problem of simply doing something by quantifying *how much* of doing something is associated with psychological outcomes *when*. Our observational study, therefore, provides important new information on the functions of ritual. Future research can extend on our research with experimental designs that can more clearly test the causal nature (e.g. random assignment of time commitments within individuals; active control conditions).

5. Conclusion

In summary, our study provides new insights into temporal effects of ritualistic performance on social and affective variables in ecologically valid ways. We report data on one of the most widely celebrated rituals in the world, demonstrating that: (i) social cohesion, affect and health responses increase on the focal day of the ritual, (ii) time investments show signs of diminishing marginal utilities, (iii) emotional responses may reinforce social effects of ritual via anticipatory affect, and (iv) ecological niche effects warrant more attention.

Ethics. The study design has been approved by the School of Psychology Human Ethics Committee under delegated authority of Victoria University of Wellington's Human Ethics Committee (no. 0000020925).

Data accessibility. The datasets and survey material supporting this article have been uploaded on the Open Science Framework: https://osf.io/pzrkv/.

Authors' contributions. R.F., J.B., P.S., S.T. developed the study design; P.S. and S.T. collected the data; R.K., J.A.K., R.F., S.T., J.B. analysed and interpreted the data; R.F. drafted the article; all authors provided input to revision and approved the final version.

Competing interests. We declare we have no competing interests.

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