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ORIGINAL ARTICLE

A new statistical model for the Day Reconstruction Method

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Abstract

The Day Reconstruction Method (DRM) is a method to measure one's subjective affective status by soliciting information in a questionnaire about the previous day's activities. We developed a new model to examine the association of daily activities, the friendliness of interacting partners, and time-of-day on net affect scores among 10,377 adults participating in the World Health Organization's Study on global ageing and adult health (SAGE). A multilevel regression was fitted and the time-of-day effect was modeled by restricted cubic spline. The net affect score was a serpentine curve; stable from 4 a.m. to 6 a.m., increased from 7 a.m. to 12 noon, and became stable onwards. Participants had the highest net affect scores during religious activities (0.48, 95% confidence interval [CI]: 0.44, 0.53), and they enjoyed leisure activities, exercising, and household responsibilities more than work. Compared with events that lacked interacting partners, activities with very friendly interacting partners were associated with higher net affect scores (0.21, 95% CI: 0.19, 0.22), but events with slightly friendly interacting partners, slightly irritating or very irritating partners had lower net affect scores. To conclude, researchers using DRM for assessing well-being status across time should include the type of activities and the friendliness of the interacting partners.

KEYWORDS

data analysis, non-linear, questionnaire, well-being, World Health Organization

1 | INTRODUCTION

Subjective well-being is important to human beings as a broadening desire beyond the absence of disease and disability (McDowell, 2010). There are many scales of well-being, and most of them measure the overall state (for example, the Psychological General Well-being Index [Dupuy, 1984]) or trait (for example, Subjective Happiness Scale [Lyubomirsky & Lepper, 1999]). However, well-being or affective state changes with time. Nobel laureate Daniel Kahneman and his colleagues developed the Day Reconstruction Method (DRM) (Kahneman, Krueger, Schkade, Schwarz, & Stone, 2004) to measure the subjective affective status of respondents by asking them to complete a questionnaire recalling their activities that occurred in the previous day, the interacting partners and the friendliness of these interacting partners in these activities, and their feelings during these activities. Using DRM, comprehensive data about the respondents' daily activities, as well as their feelings towards these activities, can be collected.

Prior to the development of DRM, other methods existed for assessing real-time well-being status with diaries (Bolger, Davis, & Rafaeli, 2003) such as the Experience Sampling Method (ESM) (Csikszentmihalyi & Larson, 1987). DRM is becoming popular because it yields affect scores similar to those of ESM (Bylsma, Taylor-Clift, & Rottenberg, 2011; Dockray et al., 2010) but is less burdensome to responders (Diener & Tay, 2014), as ESM requires multiple prompts per day, while DRM requires just one prompt. Many studies have used DRM to assess the diurnal pattern of well-being (Kahneman et al., 2004; Stone et al., 2006) and the associations between diurnal well-being level and other health-related behaviors, including physical activity level (Presseau, Tait, Johnston, Francis, & Sniehotta, 2013) and sleep problems (Jackowska, Dockray, Endrighi, Hendrickx, & Steptoe, 2012).

DRM provides information about the emotions and well-being for various activities that participants have engaged in; however most of the existing studies that explore the association between activity engagement and well-being have used the total time spent in specific activities (for example, watching television [Depp, Schkade, Thompson, & Jeste, 2010], non-work-related activities [Oerlemans & Bakker, 2014], social, physical, restful, household, and cognitive activities [Oerlemans, Bakker, & Veenhoven, 2011]). The correlation between time spent in the various activities and the level of well-being is computed. This approach ignores the effect of interacting partners and their friendliness during these activities, as well as the time-of-day

effect (wherein people are happier during lunch time and after work, and more tired in the morning and after work [Kahneman et al., 2004; Stone et al., 2006]). In view of this, we built a new model to examine the association of daily activities, the friendliness of interacting partners, and time-of-day, on net affect scores among more than 10,000 adults participating in the World Health Organization's Study on global ageing and adult health (SAGE).

2 | METHODS

2.1 | Participants

Details of the SAGE study have been published elsewhere (Kowal et al., 2012) and http://apps.who.int/healthinfo/systems/surveydata/index.php/catalog. In brief, SAGE is a longitudinal, multi-country, face-to-face interview conducted in China, Ghana, India, Mexico, Russia, and South Africa. It uses multistage cluster sampling strategies to select nationally representative samples of adults aged 50+ years and smaller samples of 18 to 49 years for comparison purposes. The interview collected data about health status, social cohesion, well-being and quality of life, and health care utilization. Here, we used the Wave 1 cross-sectional data collected in 2009–2010 (n = 10,377). Written consent was obtained from all participants.

The SAGE study was approved by the following institutions: Ethics Review Committee, World Health Organization; Ethics Committee, Shanghai Municipal Centre for Disease Control and Prevention, Shanghai, China; Ethical Committee, Ghana Medical School, Accra, Ghana; Institutional Review Board, International Institute of Population Sciences, Mumbai, India; Ethics Committee, National Institute of Public Health (INSP), Cuernavaca, Mexico; Ethics Committee, OPM (School of Preventive and Social Medicine), Russian Academy of Medical Sciences, Moscow, Russia; and Research Ethics Committee, Human Sciences Research Council, Pretoria, South Africa.

2.2 | Measurements

The abbreviated version of the DRM questionnaire was used to assess participants' daily activities and their well-being, with recall time limited to 15 minutes. The questionnaire was translated into different languages following a standard protocol, and studies using the SAGE dataset showed that the abbreviated DRM yielded comparable net affect scores to the original DRM and the two-factor model had a good fit with the seven affective status items (Ayuso-Mateos et al., 2013; Miret et al., 2012). A total of four different versions of the abbreviated DRM were administered (n = 49,725), and only participants who completed version A, were included (n = 10,377). These participants were asked to reconstruct their activities in the day previous to the questionnaire day starting with morning when they woke up. Details about the other three versions were outlined in the Discussion section. For participants completing version A, wake-up time was recorded. For each activity, the time spent, the activity type, the interacting partners, the friendliness of the interacting partners, and participants' seven feelings about this activity were reported on a 3-point scale (worried, rushed, irritated or angry, depressed, tense or stressed, calm or relaxed, and enjoying). The time spent on each activity was used to compute the starting time and ending time of the activities. The starting time of the second activity after waking up was calculated as the wake-up time plus the time spent on the first activity after waking, and the ending times of this activity were calculated as the starting time plus the time spent on this activity. The starting and ending times of the other activities were computed in a similar manner. All sleeping activities were removed, as participants were not asked to report their feelings during sleeping.

Positive affect and negative affect were defined as the average of the scores given to the positive feelings (calm or relaxed, and enjoying) and the average of those given to the negative feelings (worried, rushed, irritated or angry, depressed, and tense or stressed), respectively. Net affect was defined as the positive affect minus the negative affect, and it has a value between −2 and +2.

2.3 | Modeling of DRM

Time-of-day of the activity, type of activity, and friendliness of the interacting partners all contribute to the net affect score of that event (Kahneman et al., 2004). The time-of-day effect was modeled by restricted cubic spline with 4 knots. For participant i, the net affect score of a particular event j, Y_{ij}, would be $Y_{ij} = \beta_0 + \beta_T T_{ij} + \beta_{R1} R1(T_{ij}) + \beta_{R2} R2(T_{ij}) + \beta_{act}\text{act}_{ij} + \beta_f f_{ij} + \varepsilon_{ij}$, where $R1(T_{ij}) = (T_{ij} - C_1)^3 - (T_{ij} - C_3)^3(C_4 - C_1)/(C_4 - C_3) + (T_{ij} - C_4)^3(C_3 - C_1)/(C_4 - C_3)$ and $R2(T_{ij}) = (T_{ij} - C_2)^3 - (T_{ij} - C_3)^3(C_4 - C_2)/(C_4 - C_3) + (T_{ij} - C_4)^3(C_3 - C_2)/(C_4 - C_3)$ are the additional independent variables for modeling restricted cubic spline with 4 knots C_1, C_2, C_3, C_4, (Durrleman & Simon, 2006) and β_0, β_T, β_{act}, β_f, and ε_{ij} are the intercept, effect of time-of-day, effect of type of activity, effect of friendliness, and error term. The time-of-day of the activity was defined as the midpoint between the starting time and ending time of the activity (Stone et al., 2006). In addition, the participant-level confounder, including age, gender, and country of study (which should affect types of activities engaged), were adjusted using a multilevel regression ($Y_{ij} = \beta_0 + \beta_{age}\text{age}_i + \beta_{gender}\text{gender}_i + \beta_{country}\text{country}_i + \beta_T T_{ij} + \beta_{R1} R1(T_{ij}) + \beta_{R2} R2(T_{ij}) + \beta_{act}\text{act}_{ij} + \beta_f f_{ij} + \varepsilon_i + \varepsilon_{ij}$,), where β_{age}, β_{gender}, and $\beta_{country}$ are the effect of age, effect of gender, and effect of country of study, and ε_i is the subject-level error. All effects were set as fixed effects. A sensitivity analysis was conducted to test whether using random effects model will change the findings. We have tested different combinations of models and the model with smallest Akaike Information Criterion (AIC) (the effects of the friendliness of interacting partners are random and other effects are fixed) was presented in Supporting Information. A model without the effects of time-of-day and friendliness of interacting partners (that is, $Y_{ij} = \beta_0 + \beta_{age}\text{age}_i + \beta_{gender}\text{gender}_i + \beta_{country}\text{country}_i + \beta_{act}\text{act}_{ij} + \varepsilon_i + \varepsilon_{ij}$) was also fitted for comparison purpose. The AIC was used to compare the goodness-of-fit of the models. All statistical analyses were conducted using R 3.2.0 and restricted cubic spline was fitted using R package *rms* (Harrell Jr, 2001).

3 | RESULTS

Table 1 shows the characteristics of the sample and the events recalled. Most of the participants were from China (34.3%) and India

TABLE 1 Descriptive statistics

Individual participant (n = 10,377)	Frequency	Percentage
Country		
China	3,560	34.3%
Ghana	1,286	12.4%
India	2,769	26.7%
Mexico	644	6.2%
Russian	1,071	10.3%
South Africa	1,047	10.1%
Female	5,820	56.1%
Number of events recalled		
1	168	1.6%
2	938	9.0%
3	1,366	13.2%
4	1,667	16.1%
5	3,071	29.6%
6	1,592	15.3%
7	889	8.6%
8	398	3.8%
9	155	1.5%
10	133	1.3%
	Mean	Standard deviation
Age	57.98	14.67
Event (n = 49,849)	Frequency	Percentage
Activity type		
Working	2,914	5.8%
Subsistence farming	1,814	3.6%
Preparing food	5,182	10.4%
Doing housework	5,851	11.7%
Watching children	700	1.4%
Shopping	898	1.8%
Walking somewhere	2,586	5.2%
Traveling by bicycle	331	0.7%
Traveling by car/bus/train	796	1.6%
Rest (includes tea/coffee break)	5,074	10.2%
Chatting with someone	2,709	5.4%
Playing (includes cards/games)	198	0.4%
Reading	386	0.8%
Listening to radio	531	1.1%
Watching television	1,958	3.9%
Exercising or leisurely walk	1,115	2.2%
Other leisure activities	912	1.8%
Grooming or bathing (self)	6,356	12.8%
Eating	8,038	16.1%
Religious activity	1,324	2.7%
Providing care to someone	154	0.3%
Intimate relations/sex	22	0.0%
Interacting partners		
Alone	26,813	53.8%
Spouse	8,980	18.0%
Adult children	3,459	6.9%
Young children or grandchildren	3,690	7.4%
Family (other than spouse/children)	4,436	8.9%
Friends	3,393	6.8%
Co-workers	2,258	4.5%
Friendliness of interacting partners		
Very friendly	16,133	71.2%
Slightly friendly	6,049	26.7%
Slightly irritating	397	1.8%
Very irritating	71	0.3%
	Mean	Standard deviation
Activity duration	75 minutes 15 seconds	94 minutes 3 seconds
Positive affects	2.42	0.62
Negative affects	1.11	0.26
Net affect	1.31	0.75

(*Continues*)

(26.7%), and participant on average recalled an average of 4.80 events (standard deviation [SD] = 1.77). The three most commonly recalled events were eating (16.1%), grooming or bathing (12.8%), and doing housework (11.7%); the three least commonly recalled events were intimate relations/sex (0.04%), providing care to someone (0.3%), and playing (0.4%). More than half of the events were done alone (53.8%), and for events with interacting partners, most partners were characterized as friendly (97.9%).

Figure 1 shows the time-of-day effect on the net affect modeled using restricted cubic spline. The spline was trimmed from 0 to 4 a.m. and after 4 p.m. as there were very few recalled activities in these time periods. The net affect score was a serpentine curve; the score was stable from 4 a.m. to 6 a.m. (1.03), increased from 7 a.m. to 12 noon, and became stable (1.15) onwards.

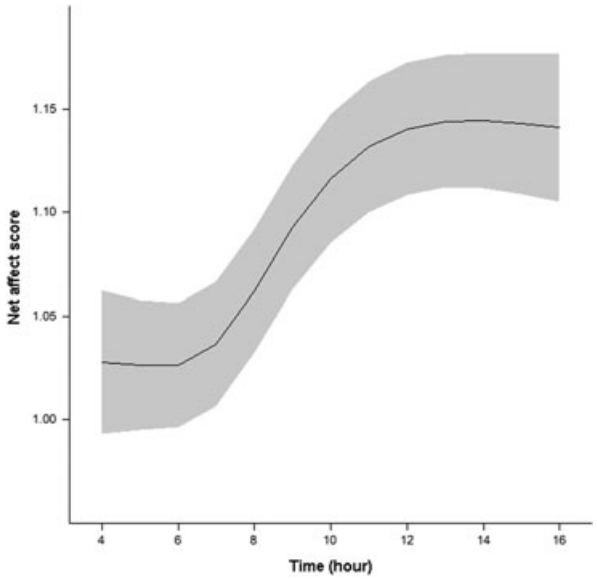

FIGURE 1 The restricted cubic spline of time on net affect

Figure 2 shows the association of different types of activity on the net affects score. Working was set as the reference activity. Participants had the highest net affects score during religious activities (0.48, 95% confidence interval [CI]: 0.44, 0.53). Participants also enjoyed leisure activities more than work. Such activities included reading (0.40, 95% CI: 0.32, 0.47), watching television (0.34, 95% CI: 0.30, 0.38), listening to radio (0.33, 95% CI: 0.26, 0.39), exercising or leisurely walk (0.31, 95% CI: 0.26, 0.36), playing (0.26, 95% CI: 0.15, 0.36), shopping (0.20, 95% CI: 0.14, 0.25), chatting with someone (0.19, 95% CI: 0.15, 0.23), and other leisure activities (0.09, 95% CI: 0.03, 0.14). Participants also enjoyed certain household responsibilities more than work; these included preparing food (0.13, 95% CI: 0.10, 0.16), watching children (0.09, 95% CI: 0.03, 0.15), and doing housework (0.05, 95% CI: 0.02, 0.08). In contrast, and they enjoyed work more than subsistence farming (−0.14, 95% CI: −0.18, −0.10).

Compared with events they experienced alone, participants had higher net affect scores for events with very friendly interacting partners (0.21, 95% CI: 0.19, 0.22), but had lower net affect scores for events with a slightly friendly (−0.26, 95% CI: −0.28, −0.24), a slightly irritating (−0.81, 95% CI: −0.88, −0.74), or very irritating (−0.86, 95% CI: −1.03, −0.70) interacting partners.

Supporting Information Figure S1 shows the association of different types of activity on the net affects score without adjusting for the effects of time-of-day and friendliness of interacting partners. This model had worse goodness-of-fit (AIC 26,434) than the adjusted model (AIC 25,037). Also, the net affects score for some activities yielded from the unadjusted model overestimated that of the adjusted model, in particular eating (0.26 versus 0.32) playing (0.26 versus 0.36), chatting with someone (0.19 versus 0.26), and intimate relations/sex (−0.01 versus 0.07).Supporting Information Figure S2 shows the association of different types of activity on the net affects score with the effects of the friendliness of interacting partners set as random. Compare this with Figure 2, the rankings of the types of activity yielded from the two models were very similar as shown by the strong correlation (Spearman correlation 0.76, $p < 0.001$) of their parameter estimates.

4 | DISCUSSION

This study demonstrated a statistical analysis method of DRM by regressing the net affect scores by age, sex, country, time of the event, type of activity, and friendliness of the interacting partners. The participants, who came from six countries that together represent more than 40% of the world population (Population Division of the Department of Economic and Social Affairs of the United Nations Secretariat, 2015), had the highest net affect during religious activity and the lowest net affect during subsistence farming. This finding is similar to the pattern seen in a previous study with seniors, where time spent in social and physical activities were positively associated while household activities were negatively associated with happiness (Oerlemans et al., 2011). In addition, this study found that activities accompanied by very friendly interacting partners were associated with higher net affect scores and that being alone was better than having interacting partners who were irritating. Results obtained using this analytic approach are important for further intervention studies encouraging health-promoting behaviors. For example, in organizing physical exercise programs, a friendly atmosphere and an appropriate time (lunch time) would be expected to enhance participants' affect and thus increase participation rates and compliance. Another example would be to reduce the possibility of employee burnout by arranging for low-effort work to take place in the morning when net affect is at its nadir (Oerlemans & Bakker, 2014).

The diurnal pattern of net affect score obtained in this study was a serpentine curve, which is very different from previous findings of a V-shape curve (Kahneman et al., 2004; Stone et al., 2006). Since the crude time-of-day effect on net affect modeled with a restricted cubic spline (Figure 3) demonstrated a V-shape curve, we postulate that the effect of time on net affect was confounded by the type of activity. Figure 4 plots the type of activity (sorted according to net affect score in descending order) and the distribution of the time of occurrence. Time of occurrence of different activities was different ($\eta^2 = 0.08$, a small-to-medium effect size), and there was a trend that earlier

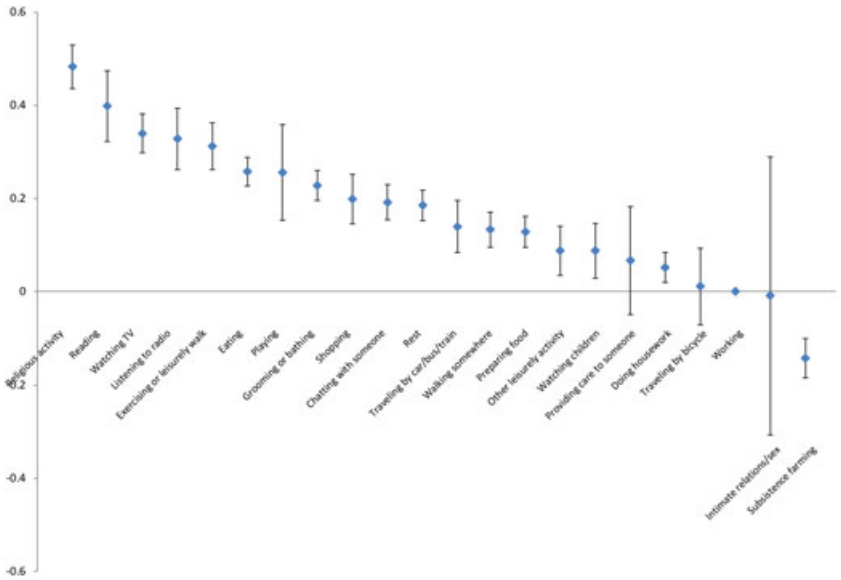

FIGURE 2 The association of different types of activity on net affect

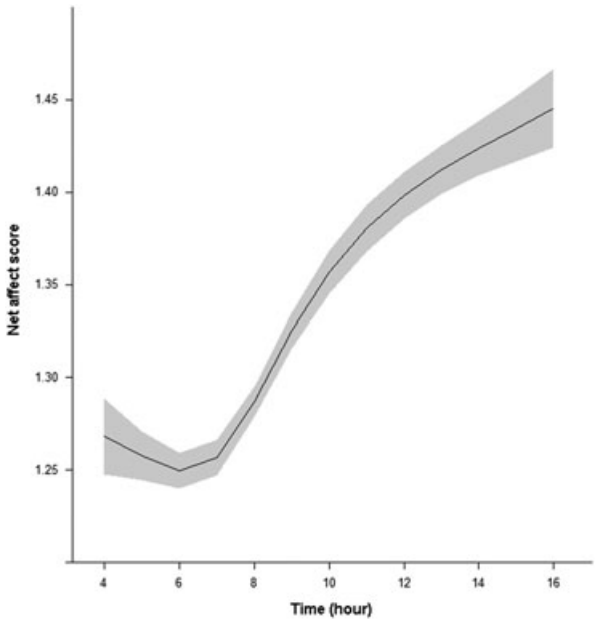

FIGURE 3 The crude restricted cubic spline of time on net affect

activities had lower net affect scores. For example, subsistence farming, the lowest ranked activity, occurred at 7:51 a.m. on average, while television-watching, the third-ranked activity, occurred at 10:00 a.m. on average. Given these findings, the crude diurnal pattern was confounded and activity type should be adjusted for (Lee, 2014) with our proposed model.

There are limitations in the present study. First, only participants who completed version A of the DRM, that is, recalling the activities in the day previous to the questionnaire day and starting with the morning when they woke up, were included. Participants completing versions B (recalling from the afternoon on the day previous to the interview day), C (recalling from the evening on the day previous to the interview day), and D (recalling events, friendliness of interacting partners, and affective status in parts of the day instead of each activity on the day previous to the interview day), were not included in the current analysis. Therefore, most of the recalled activities occurred in the morning, and very few participants reported having intimate relations/sex (0.04%). We chose to analyze only one set to ensure that the reported activities are comparable within our sample, and we believed that sets A, B, and C are incomparable as the activities occurred in the morning, afternoon, and evening would be very different. A second limitation is that only age, sex, and country of study were adjusted for in the final model. While it is very likely that other confounders exist, the aim of this study is to illustrate a new statistical analysis method for DRM data, and we believe that researchers who pursue further analysis of DRM data should adjust for other appropriate confounders on their own. Lastly, although the net affect score of DRM has been validated against ESM, the other components including time-of-event, type of activity, and friendliness of interacting partners, have not been validated.

The statistical model used in the current study assumed that one's well-being level at a particular time is affected by what he/she is doing at that moment. This assumption, and other current analysis of DRM data, ignored the possibility that affect would also be influenced by what he/she had done before. Further studies on building models to investigate the ways that previously occurring activities impact current well-being level are warranted.

The questionnaire itself might lead to measurement reactivity that the measurement itself was changing the participants' net affects (French & Sutton, 2010). In particular, the length of the DRM questionnaire (up to 15 minutes for abbreviated version) might anger the participants. Although we have not examined the effects of measurement reactivity, we believe that it was kept minimal as there were only 10 questions corresponding to one activity, and on average the participants recalled less than five activities.

To conclude, researchers using DRM for assessing well-being status across time should consider including the type of activities and the friendliness of the interacting partners in their statistical models. Further studies examining the factors affecting net affect score should also adjust for these variables.

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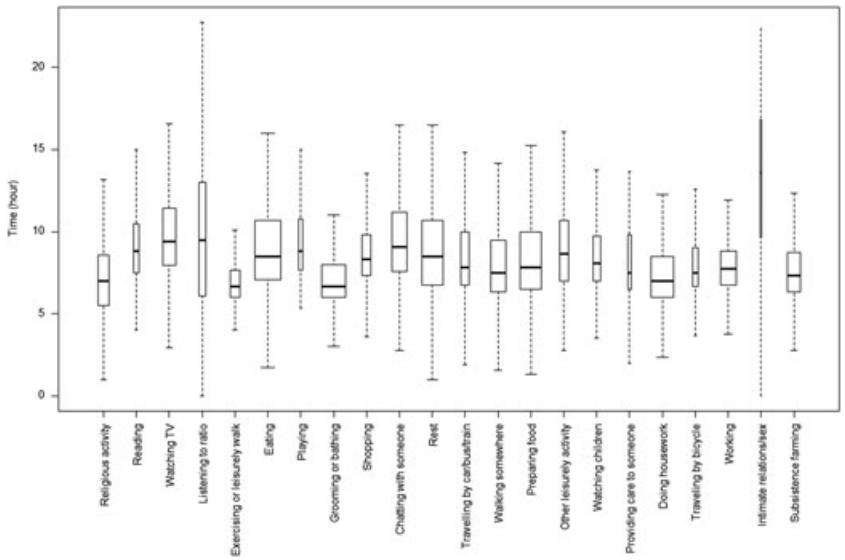

FIGURE 4 The type of activity and the distribution of their occurrence time

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DECLARATION OF INTEREST STATEMENT

The authors declare that they have no conflict of interest.

CONTRIBUTORS

PHL conceived the study, conducted the data analysis, and drafted the manuscript. ACYT and KYL interpreted the results and substantially revised the manuscript.

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SUPPORTING INFORMATION

Additional Supporting Information may be found online in the supporting information tab for this article.

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