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Fathers have lower salivary testosterone levels than unmarried men and married non-fathers in Beijing, China

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A growing body of evidence, almost entirely from North America, has found that male testosterone levels are positively associated with mating effort (male–male competition and mate-seeking behaviour), while lower testosterone levels have been associated with affiliative pair bonding and paternal care. To expand the cross-cultural scope of this research, here we investigate variation in salivary testosterone levels among Chinese men in relation to marital and parenting variables. One hundred and twenty-six men drawn from a Beijing university setting between the ages of 21 and 38 completed a questionnaire and provided both morning and late afternoon saliva samples from which testosterone levels were measured. The 66 unmarried men had slightly higher levels of testosterone than the 30 married non-fathers, but this difference was not statistically significant. However, the 30 fathers exhibited significantly lower testosterone levels than both unmarried men and married non-fathers. Among married non-fathers, marital relationship quality was not significantly related to testosterone levels. Among married fathers, men with children aged less than 4 years of age did not have lower testosterone levels than men with older children. These data are the first outside of North America to show lower testosterone levels among fathers, and lend support to the theoretical view that male testosterone levels differ according to mating and parenting effort.

Keywords: marriage; fatherhood; endocrinology; Asia; cross-cultural

1. INTRODUCTION

A key social dimension of human male life histories is pair bonding, referring to the maintenance of a long-term relationship with a mate, together with paternal care (Kaplan & Lancaster 2003). Humans number among the approximately 5% of mammalian species that form long-term bonds with mates and provide paternal care (Clutton-Brock 1991; Reichard & Boesch 2003). These behaviours appear to have been derived recently during hominid evolution (Marlowe 2000; Gray *et al.* 2004*a*). Cross-cultural and historical variation in pair bonding and paternal care have been recognized (Whiting & Whiting 1975; Hewlett 1992; Low 2000).

Recently, a growing body of human research has shown that pair bonding and parental care may also be associated with variation in male testosterone levels. Four North American studies have found lower testosterone levels among married men compared with their unmarried counterparts (Booth & Dabbs 1993; Mazur & Michalek 1998; Gray *et al.* 2002, 2004*b*). Three other North American studies have shown that men involved in committed relationships, although unmarried, also have lower testosterone levels than uncommitted single men (McIntyre *et al.* submitted; Burnham *et al.* 2003; Gray *et al.* 2004*a*). Two of these same studies found that fathers tended to have lower testosterone levels than married non-fathers, but these differences were not statistically significant (Gray *et al.* 2002; Burnham *et al.* 2003). Two other studies have examined variation in testosterone levels among married men in relation to marital outcomes (Julian & McKenry 1989; Cohan *et al.* 2003), and Mazur & Michalek (1998) have reported higher testosterone levels among men around the time of divorce. Outside of North America, two small studies failed to show differences in testosterone levels between unmarried and monogamously married (married to one wife) men (Flinn *et al.* 1998; Gray 2003). However, one of these studies found that polygynously married Kenyan men, all of whom had two wives, had higher testosterone levels than other men in the sample (Gray 2003). Three different studies of Canadian fathers revealed lower testosterone levels associated with paternal care (Storey *et al.* 2000; Berg & Wynne-Edwards 2001; Fleming *et al.* 2002).

Few data on the social correlates of human male testosterone levels are available in non-Western cultures (Dabbs & Dabbs 2000; Christiansen 2001; Morley 2003), and no such data, to our knowledge, have previously been

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published on Asian men. This question is of great interest, given the substantial differences between East and West in cultural attitudes towards family responsibility and parental care.

In light of these observations, we sought to test whether differences in pair bonding and parental status would be associated with differences in testosterone levels among young men in Beijing, China. Specifically, we tested the following predictions: (i) married non-fathers will have lower testosterone levels than unmarried men; (ii) fathers will have lower testosterone levels than married non-fathers; (iii) among married non-fathers, testosterone levels will be negatively associated with relationship satisfaction; and (iv) among fathers, those whose youngest child is aged less than 4 years will exhibit lower testosterone levels than those whose youngest child is 4 years of age or older. The rationale for these predictions follows from the view that testosterone appears to be positively associated with male mating effort (male–male competition and mate-seeking behaviour) and negatively with involvement in affiliative pair bonding and direct paternal care—especially care that involves holding and carrying young children (Wingfield *et al.* 1990; Gray *et al.* 2002). In this Chinese context, we expected reduced mating effort among married men, especially fathers, compared with unmarried men. We also expected that fathers of young children would be engaged in more paternal care that involved holding or carrying the child, and would be engaged in less mating effort than fathers of older children—factors both likely linked to lower testosterone.

To test these predictions, potentially confounding variables of age, body composition and time of sample collection should be considered (Nelson 2000; Zietzmann & Nieschlag 2001). Age-related declines in testosterone levels are well recognized (Vermeulen *et al.* 1996). Because most studies including overweight subjects have observed an inverse relationship between testosterone levels and body mass index (BMI), BMI is also a potential confounder. Testosterone displays a circadian rhythm, with peak levels in early morning and declines across the day. Moreover, since a number of studies have observed greater behaviour–testosterone effect sizes in afternoons and evenings (reviewed in Gray *et al.* 2004*a*), testing predictions both in morning and late afternoon samples enables determining whether predictions are better supported at times later in the day.

2. MATERIAL AND METHODS

(a) *Study population*

Using posted advertisements and word of mouth, we recruited male students and faculty members at a university in Beijing, China. Although our protocol required that subjects be between the age 25 and 35, five of the subjects fell outside this range; four were between the age 21 and 24 and one was at an age of 38. Participants in this study were mostly well educated, and tended to be proficient in both Chinese and English. Accordingly, the questions and instructions listed on the questionnaires were provided in both Chinese and English. Permission to conduct this study was obtained from the appropriate host university officials and the Harvard University Institutional Review Board. No identifiers were used on saliva samples or questionnaires, ensuring both anonymity and confidentiality of responses and testosterone levels. Subjects were reimbursed with 100 Renminbi (roughly the equivalent of US$12) for participating in the study. We recruited a total of 126 evaluable subjects—66 single men, 30 married non-fathers and 30 married fathers. All of the 30 fathers had precisely one child, thus improving the uniformity of this group.

(b) *Questionnaire*

Subjects were each asked to complete a questionnaire containing basic demographic information and a relationship satisfaction scale (Hendrick 1988). This relationship satisfaction scale asks subjects to respond to seven questions regarding their relationship satisfaction, each on a 1–7 Likert scale, yielding a total score between 7 (least satisfaction) and 49 (greatest satisfaction). This scale is well established in studies of Western populations (Hendrick 1988). In our Chinese sample, the scale showed good reliability (Cronbach's $\alpha = 0.89$). The questionnaire, including the relationship satisfaction scale, was translated and back-translated by four independent Chinese colleagues, two of whom did not know the original English text. A provisional version was piloted to 10 Chinese graduate students studying at an American university. The final version was fixed by consensus to ensure a careful cultural adaptation.

(c) *Sample collection*

The primary dependent variables in this study were morning and afternoon salivary testosterone levels. Times of morning sample collection ranged between 07.30 and 12.20 (though this latter time falls outside morning, we nonetheless refer to these as 'morning' samples for simplicity). Times of afternoon samples were between 16.00 and 17.20 (with exception of one person whose sample was taken at 18.40). It was not possible to schedule subjects for morning saliva collection during a shorter window of time due to subjects' scheduling constraints. All samples were collected at a designated university location under the observation of the investigators.

The measurement of testosterone levels in saliva has been previously validated and yields testosterone (T) levels highly correlated with serum levels (Read 1993). Indeed, the unbound testosterone, as measured in saliva, may be even more relevant to behaviour than serum testosterone, because it better represents biologically available testosterone (Vining & McGinley 1987). Saliva samples were collected after instructing subjects to rinse out their mouths with cool, clean water, chew a stick of gum for 1 min and then salivate into a polystyrene tube that contained sodium azide as a preservative (Ellison 1988; Lipson & Ellison 1989). The tubes were kept at room temperature in China for three months before subject to assay. Previously, it has been found that saliva samples can be stored at room temperature for four to six months without altering hormone levels (Lipson & Ellison 1989), and thus this time frame is not expected to alter T-levels.

Saliva samples were assayed for testosterone using previously published ^{125}I radioimmunoassay techniques (Granger *et al.* 1999). This assay protocol involves modification of a commercially available serum testosterone kit produced by Diagnostic Systems Laboratory, Inc. (Webster, TX). Assay kits were shipped to Beijing, where assays were run at the China–Japan Friendship Hospital. Samples were run in two assay batches. Interassay coefficients of variation were 14.0% for low pools and 7.4% for high pools.

Table 1. Descriptive demographic and contextual data according to relationship status. (All data are mean (s.d.). *Significant group differences ($p<0.05$) in the variable according to ANOVA.)

variable	unmarried men, $n=66$	married non-fathers, $n=30$	married fathers, $n=30$	all men, $n=126$
age	25.8 (1.9)	27.5 (2.5)	31.2 (3.0)	27.6 (3.2)*
BMI (kg m^{-2})	21.1 (2.5)	21.6 (2.6)	22.5 (3.2)	21.5 (2.7)
relationship satisfaction	—	40.8 (5.3)	35.5 (8.5)	38.7 (7.1)*
number (%) of subjects having more than one sex partner in the previous year	11 (18)[a]	7 (23)	5 (26)[b]	23 (21)[c]
number (%) of subjects expecting more than one sex partner in the next 5 years	20 (31.3)[a]	12 (40)	6 (33)[b]	39 (34)[c]
masturbation frequency (number of times per week)	1.2 (1.7)	0.9 (1.1)	0.2 (0.4)	0.9 (1.4)*

[a] $n=63$, because some subjects did not provide information.
[b] $n=19$, because some subjects did not provide information.
[c] $n=112$, because some subjects did not provide information.

Table 2. Testosterone data according to relationship status. (a.m. Testosterone data adjusted: data are age-restricted (25–35 years old) and time-restricted (collection times between 08.00 and 10.00), and adjusted for age, BMI and time of collection. p.m. Testosterone data adjusted: data are age-restricted (25–35 years old) and time-restricted (collection times between 16.00 and 17.20), and adjusted for age, BMI and time of collection. Significance of differences versus controls: *$p<0.05$, **$p<0.02$, ***$p<0.01$., ****$p<0.001$.)

	estimated mean differences in log-transformed testosterone (s.e.) between groups					
	single versus married		married versus fathers		single versus fathers	
	a.m.	p.m.	a.m.	p.m.	a.m.	p.m.
unadjusted	0.18 (0.16)	0.10 (0.14)	0.48 (0.19)**	0.34 (0.17)*	0.66 (0.16)****	0.44 (0.14)***
adjusted	0.20 (0.25)	0.13 (0.15)	0.75 (0.35)*	0.32 (0.21)	0.94 (0.35)***	0.45 (0.21)*

(d) *Statistical analysis*

The participants' morning and afternoon salivary testosterone levels were log-transformed because of their skewed distribution. For each of these two outcome variables, our primary analysis compared single men, married non-fathers and fathers, *separately* using multivariate linear regression. We performed this analysis initially without adjustments; then, to test the stability of our estimates, we repeated these analyses while adjusting for age, BMI and time of sample collection, and again while restricting the sample to exclude outliers with regard to age, time of sample collection and values of testosterone (see details of these analyses below). For prediction (iii), we used linear regression, with the sample restricted to married non-fathers, and with relationship satisfaction, modelled as a continuous variable, as the predictor variable. We performed this analysis without adjustment and then again with adjustment for age, BMI, time of morning collection while restricting age and time of sample collection. For prediction (iv), we used linear regression, with the sample restricted to fathers, and with the age of the youngest child modelled as a binary variable (less than 4 years of age versus 4 years of age or older) as the predictor, again performed both with and without adjustment for the age, BMI and time of sample collection.

In a subsequent *a posteriori* analysis, we subdivided the single men into those who were in a committed relationship (at least three months with the same partner) and those who were uncommitted, and examined salivary testosterone levels in these subgroups.

All p-values reported are two-tailed, with α set at $p=0.05$.

3. RESULTS

(a) *Demographic measures*

Table 1 displays demographic data for the three groups of men: unmarried men, married men without children and married fathers. The group of unmarried men included 15 men who reported being involved in a relationship and 51 uncommitted men. We found no significant differences between the 15 committed and 51 uncommitted men on any of the variables in table 1. Thus, we include these paired men within the category of unmarried men.

(b) *Association of testosterone levels with relationship status*

Both morning and afternoon salivary testosterone levels were significantly lower in fathers than in married non-fathers or unmarried men (table 2; figure 1). The difference between unmarried men and married non-fathers was in the predicted direction, but did not reach significance. Morning and afternoon salivary testosterone levels were highly correlated within individuals (Spearman's $\rho=0.629$, $p<0.0001$, see figure 2).

We then repeated these analyses (1) using an age-restricted sample that excluded the four men under age 25 and the one man over age 35; (2) using this age-restricted sample and additionally adjusting for age as a continuous variable; and (3) repeating analysis (2) with adjustment for BMI, modelled as an ordered category of five quintiles. None of these exercises resulted in any appreciable change in the estimated mean differences between groups, or changes in the significance levels for these differences.

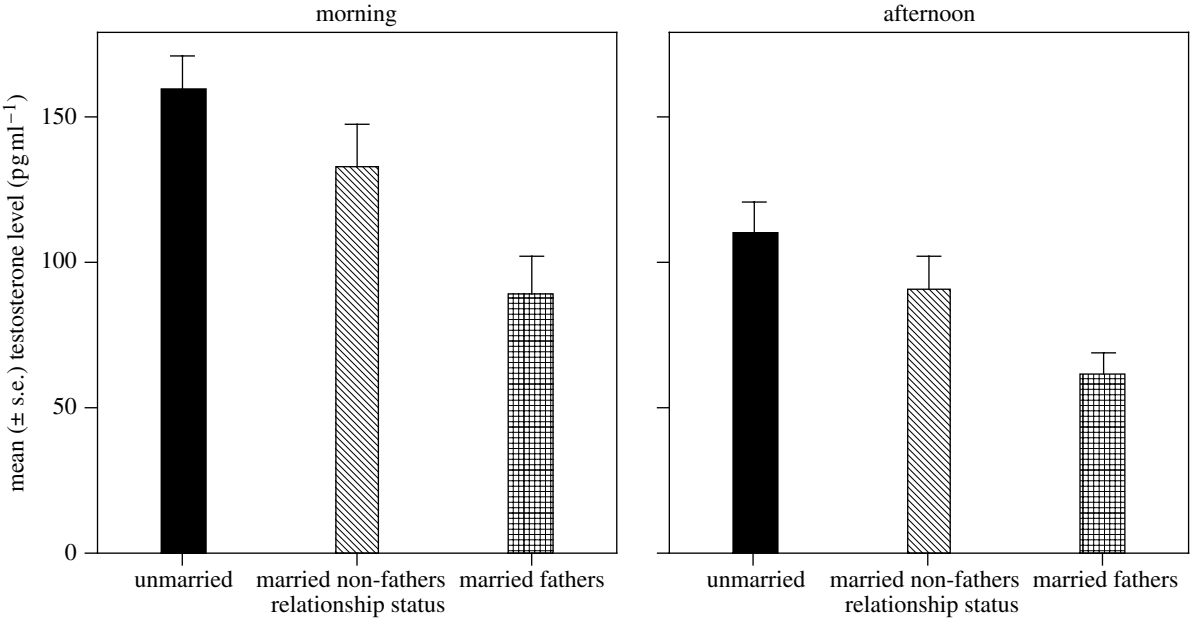

Figure 1. Fathers have significantly lower morning and afternoon testosterone levels than married non-fathers and unmarried men in both univariate and multivariate analyses ($p<0.05$). In the mornings, these differences represent 33% lower testosterone levels among fathers compared with married non-fathers, and 44% lower testosterone levels among fathers compared with unmarried men. In the afternoons, these differences represent 32% lower testosterone levels among fathers compared with married non-fathers and 44% lower testosterone levels among fathers compared with unmarried men.

In an *a posteriori* analysis, we examined the two subgroups of unmarried men: 51 who were not in a committed relationship and 15 men who were unmarried, but in a committed relationship. The 15 committed but unmarried men displayed testosterone levels intermediate between the 51 uncommitted men and the 30 married non-fathers (mean (s.d.) morning testosterone levels 162.5 (100.2), 149.1 (63.7) and 132.2 (84.1) for the three groups, respectively; mean afternoon testosterone levels 115.0 (98.0), 92.0 (45.7) and 90.5 (61.9)). We then repeated our analyses of testosterone levels and relationship status while pooling the 15 unmarried but committed men with the 30 married non-fathers—yielding a new 'split' of 51 uncommitted men, 45 committed men and 30 fathers. This new split produced estimated mean differences and significance levels very similar to those with the original split used in our primary analysis.

When we compared the testosterone levels of the 51 uncommitted single men with levels in the 60 married men (i.e. pooling fathers and non-fathers), the difference was significant for both morning and afternoon testosterone in the unadjusted analysis ($n=111$; difference (s.e.) in log-transformed morning testosterone level for uncommitted single men minus married men: 0.42 (0.15), $p=0.005$, $n=111$; for afternoon testosterone, 0.28 (0.13), $p=0.032$). However, after restriction and adjustment (using the methods described in the legend of table 2), these differences failed to achieve significance ($n=76$; morning, 0.38 (0.26), $p=0.15$, $n=65$; afternoon, 0.18 (0.16), $p=0.27$).

(c) *Association of testosterone levels with relationship satisfaction and with age of youngest child*

Among the 29 married non-fathers who completed the relationship satisfaction scale, the association between relationship satisfaction and testosterone levels was in the predicted direction, but did not reach significance

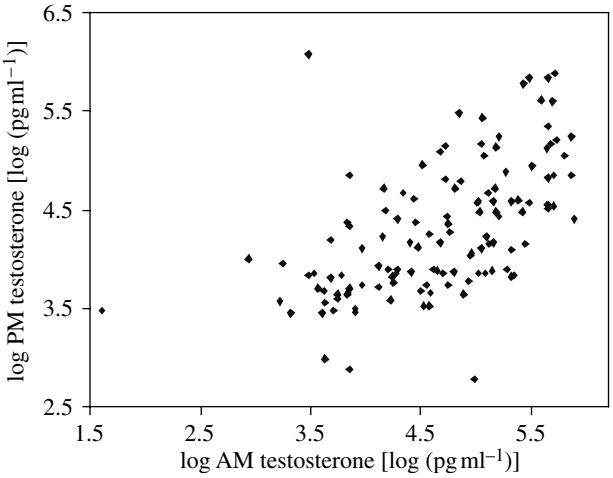

Figure 2. Morning and afternoon salivary testosterone levels were highly correlated within individuals (Spearman's $\rho=0.629$, $p<0.0001$).

(estimated mean change (s.e.) in log-transformed morning testosterone level for every increase of 1 point on the scale: -0.03 (0.02), $p=0.16$ unadjusted; -0.05 (0.03), $p=0.05$ adjusted; change in afternoon testosterone levels: -0.02 (0.02), $p=0.45$ unadjusted; -0.04 (0.02), $p=0.09$ adjusted).

Among fathers, all 30 of whom had exactly one child, having a child less than 4 years of age was not associated with lower morning testosterone levels (estimated (s.d.) difference in log-transformed morning testosterone levels between fathers with children aged less than four years minus other fathers: 0.02 (0.32); $p=0.94$; change in afternoon testosterone levels -0.07 (0.19), $p=0.71$). Adjustments did not change these results. We also found no differences approaching significance when we repeated these analyses while modelling the age of child as a continuous, rather than binary variable.

4. DISCUSSION

On the basis of previous data from North America, we hypothesized that single men in China would exhibit higher salivary testosterone levels than married non-fathers, and that married non-fathers, in turn, would exhibit higher levels than married fathers. In a study of 126 men at a Beijing university, we found differences in the predicted direction: single men showed slightly (though not significantly) higher levels than married non-fathers, and both single men and married non-fathers showed significantly higher levels than married fathers. These results held both for morning and afternoon testosterone determinations, and both in univariate analyses and in analyses controlling for potential confounding variables. To our knowledge, these Chinese data are the first outside of North America to demonstrate lower testosterone levels associated with marriage and fatherhood.

We also predicted that among married non-fathers, marital satisfaction would be negatively related to testosterone levels. Among the 29 married non-fathers in our sample, we found an association in the predicted direction, which approached statistical significance in adjusted analyses using two-tailed tests. Our final prediction—that men with a child under 4 years of age would show lower testosterone levels than fathers of older children—was not supported.

How do we account for the primary findings of this study—that testosterone levels of unmarried men were (non-significantly) higher than married non-fathers, and that both unmarried men and married non-fathers had significantly higher testosterone levels than fathers? These results can be situated within the socio-cultural context of contemporary Chinese marriage and fatherhood (Bullough & Ruan 1994). Legally, men may marry at age 22 and are restricted to one wife (Xia & Zhou 2003). Marriage in urban and rural China recognizes the role of companionship, emotional satisfaction and romantic attachment (Jankowiak 1995; Pimentel 2000). However, increases in mistresses and prostitutes in larger cities mean that some pair-bonded men are not sexually exclusive (Suiming 2004). As fathers, men tend to be involved little with direct care of infants, such as holding or carrying them, but spend more time with older children (Jankowiak 1992; Shwalb *et al.* 2004; Yang *et al.* 2004). Increases in father–child intimacy in recent years appear to reflect living in physically small households, changing values regarding the roles of men, and the fact that more women are working outside the home (Jankowiak 1992).

Our data also add to a growing body of evidence that pair bonding and/or parenting may serve as relevant predictors of male testosterone variation. In turn, these data fit within a theoretical framework postulating elevated male testosterone associated with mating effort (male–male competition, mate seeking) and lower testosterone levels associated with affiliative pair bonding and paternal care (Gray *et al.* 2002). In other words, the lower levels of testosterone in fathers may reflect both their withdrawal from the competitive arena, and their involvement in paternal care.

Looking more closely at the comparison of testosterone levels between unmarried men and married non-fathers, why did differences between these groups fail to reach significance, whereas in North America significant differences have been found? One possibility is simply a Type II error in the Chinese sample, due to the moderate sample size and high standard deviation of the salivary testosterone levels in this sample. An alternative possibility is that these Chinese subjects experience less cohesive pair-bonding dynamics compared with North American subjects, in turn meaning that these married Beijing men show a less dramatic decline in testosterone levels with pair bonding. One line of evidence consistent with the notion of less cohesive Chinese marital bonds is suggested by data in table 1, in which many Chinese married non-fathers have had more than one sex partner during the past year and/or anticipate having more than one sex partner during the next five years. These findings suggest that a high proportion of Chinese men are utilizing the increased access to mistresses/prostitutes (Suiming 2004) relative to the United States (Laumann *et al.* 1994: p. 189). Interestingly, however, married non-fathers reporting more than one sex partner during the previous year did not have higher testosterone levels than monogamous married non-fathers ($p \geq 0.31$ for morning and afternoon levels, in both adjusted and unadjusted analyses). Reporting biases should also be considered here, since sexual activity was assessed only by self-report.

Several limitations of this study should be considered. First, our modest sample size, together with the large standard deviation of the salivary testosterone measurements, limited our statistical power. Thus, failure to reject the null hypothesis in some cases may have represented a Type II error. In particular, (1) the difference in testosterone levels between single men and married non-fathers and (2) the association between testosterone levels and marital satisfaction—both of which were in the predicted direction—may have failed to reach statistical significance because of inadequate power. Finally, (3) our comparison of fathers with younger versus older children is very limited in power, since there were only 19 and 11 fathers in each group, respectively.

Another limitation of our design is that it is cross-sectional rather than longitudinal or experimental. Thus, whether lower testosterone men are more inclined to fatherhood, or whether fatherhood causes lower testosterone cannot be resolved here, although both processes are reasonable (see Gray *et al.* 2004*b*). More detailed measures of marital and paternal relationships would also be desirable. Moreover, conclusions of this study are probably limited to urban settings in China, rather than the entire country. For example, given the concerns with the male-biased sex ratio in China (Hudson & Den Boer 2002), researchers have speculated that the large numbers of unmarried men may represent societal risks; since our data are restricted to a well educated university setting in Beijing in which unmarried subjects probably have prospects of finding mates, these findings may not be applicable throughout the country.

In summary, our data show that Beijing fathers have lower testosterone levels than their unmarried male and married non-father counterparts. Despite socio-cultural differences, these findings of lower testosterone levels among fathers are consistent with data from North America. These observations suggest that associations of testosterone levels with pair bonding and/or paternal care may represent widely generalizable phenomena, and hence deserve further investigation in cross-cultural settings.

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