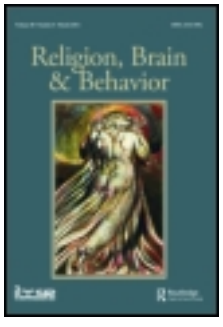

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Glossolalia is associated with differences in biomarkers of stress and arousal among Apostolic Pentecostals

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Glossolalia is associated with differences in biomarkers of stress and arousal among Apostolic Pentecostals

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The influence of glossolalia or "speaking in tongues" on biological stress and arousal is examined in a sample of Apostolic Pentecostals. Glossolalia is a form of dissociation considered by Pentecostals as possession by the Holy Spirit. Dissociation is a psychological term for partitioning of awareness and widely held to moderate stress, yet this has been difficult to affirm in culturally embedded situations. We sought to determine if glossolalic dissociation is associated with biomarkers of stress and arousal (salivary cortisol and alpha-amylase, respectively) on a religious service and a non-service day among 52 participants. We used mixed qualitative and quantitative methods to group participants as high- and low-glossolalists for preliminary comparisons and by status within their respective churches for regression analyses. Results indicate a significant influence of two glossolalia indicators on cortisol and alpha-amylase on both days, in addition to a statistically significant though not robust interaction effect between lifetime glossolalia experience and church status on the non-service day. Combined, these data suggest glossolalia experience is associated with increased physiological stress during worship and reduced stress and arousal beyond the worship context.

Keywords: biomarkers; Pentecostalism; stress; glossolalia; dissociation; alpha-amylase; cortisol

Introduction

Religious practice and spiritual faith may influence psychological processes and health in part by moderating stress (Koenig & Cohen, 2002). "Stress" is conceived of as "the nonspecific response of the body to any demand" (Selye, 1984). As environmental changes occur throughout one's lifetime, the body makes adjustments to the set-points of stress response to maintain stability. This stability through change is termed "allostasis" (McEwen & Wingfield, 2007). Cultural practices may influence such change in positive, neutral, and negative ways (Selye, 1984). The ecstatic activities of religious worship and the negative encounters of daily life,

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among others, are all considered potential stressors, given that they place a person in a challenge state (Lewis, 2003; McEwen, 2005; Winkelman, 2010). It is important to understand the influences of these ubiquitous activities on such a basic aspect of human biology, as it may shed some light on the pervasiveness of religious practices in human evolutionary history.

Previous analyses indicate an influence of the degree of Pentecostal religiosity or religious commitment and expression on general stress (Lynn, Paris, Frye, & Schell, 2010). This analysis explores the specific mechanisms of that religiosity. In considering the influence of religious worship on the stress-mediation process, Apostolic Pentecostals are an ideal population to explore. Pentecostalism is a charismatic form of evangelical Protestantism that emphasizes personal experience with the divine through "gifts of the spirit," such as glossolalia ("speaking in tongues"). Apostolics are traditional Pentecostals that emphasize glossolalia as the primary signifier that one has accepted Christ as personal savior (Synan, 2004). Glossolalia is held to manifest via a dissociative hyper-arousal state of worship (Goodman, 1972). This dissociative state is the *embodiment* of Pentecostal practice, which refers to "the impact of ongoing bio-contextual dynamics on physical form, functions, and capacities" (Worthman & Costello, 2009, p. 283). Through repeated experience of this culturally-mediated arousal, there may be an allostatic change in the set-points of stress response, as found in experienced meditators (Infante et al., 2001; MacLean et al., 1997).

A non-invasive and robust means to measure physiological stress for examining allostasis is through analysis of biomarkers in saliva. Cortisol, a key hormone of the hypothalamic–pituitary–adrenal (HPA) axis (Hellhammer, Wüst, & Kudielka, 2009), and alpha-amylase, a digestive enzyme that correlates with sympathetic nervous system (SNS) activity (Nater & Rohleder, 2009), can be measured in saliva. The HPA axis and SNS are the primary systems of biological stress response. Stressors trigger the activation of nerve cells within the SNS to release norepinephrine from neurons adjacent to salivary ducts, which leads to increased salivary alpha-amylase production. Alpha-amylase is thus an indirect indicator of physical and psychological arousal, a nonspecific form of stress (Nater & Rohleder, 2009). Following norepinephrine release, the HPA axis is activated to restore homeostasis through the release of glucocorticoids (cortisol in humans) from the adrenal cortex. Because cortisol and alpha-amylase release cycles daily, several samples throughout a day over multiple days are generally used to establish a diurnal profile (Adam & Kumari, 2009; Rohleder & Nater, 2009).

We used these salivary biomarkers to test the theory that culturally normative dissociation in the form of glossolalia would reduce physiological measures of stress and arousal among Pentecostals. The study assessed Apostolic Pentecostals in New York's Hudson Valley from September 2006 to June 2009 and investigated whether successive experiences with culturally-moderated arousal, via glossolalia, would result in lower arousal and stress during non-worship times. It was hypothesized that glossolalia experience stimulates arousal and, over time, entrains stress response, reducing arousal and stress reactions to normal daily stressors. It was predicted that (1) salivary cortisol and alpha-amylase would reflect similar arousal among all Apostolics on Sunday, when the kinetic or highly energetic activities of experiential worship (including glossolalia as well as singing and ecstatic movement) would stimulate stress response, but (2) would be lower on a non-worship day among those with more glossolalia experience.

Methods and materials

Congregation and participant recruitment

Ethnographic data was collected at six Charismatic churches by the first author over the course of nearly 1 year, including field notes relating to observations, conversations, and informal interviews with church members and transcriptions of 15 semi-structured interviews. Two Apostolic congregations in Poughkeepsie and Kingston, NY were recruited for biomarker and questionnaire data collection. Prior to data collection, the study was explained to each congregation en masse. Potential participants had to be at least 18 years old and less than 25 weeks pregnant (Obel et al., 2005).

One hundred and five individuals were approached. Seventy-three (70%) were enrolled, though 13 either dropped out or did not sufficiently complete the study protocol to be included. Five were excluded from analyses because they reported using medications known or suspected to confound glucocorticoid and catecholamine measures, and three smokers were excluded (Kirschbaum & Hellhammer, 2007; Rohleder & Nater, 2009). Fifty-two participants (mean age = 33.3, SD = 11.16, range = 18–69) took part in this portion of the study. There were 25 males and 27 females. Study dropouts and those declining to participate were evaluated with regard to known variables (including age, sex, education, church attended, church status, and glossolalia experience) using ethnographic data about church memberships and are not different from those included in the analyses.

Participants received $50 compensation for full participation. Participating churches provided letters of support, and all protocols were approved by the University at Albany Institutional Review Board.

Questionnaires

A glossolalia questionnaire (see Appendix 1) was designed based on observations and interviews. It is a seven-item questionnaire that uses ordinal scales to query how many times glossolalia has been experienced in one's lifetime (0, 1–5, 6–10, 11–20, 21–50, 51–100, or >100); duration (never, <10 s, 10–30 s, 30–60 s, 1–5 min, 5–15 min, 15–30 min, or >30 min), intensity (never, not at all, not very, neutral, somewhat, very, or extremely), and frequency of average experiences (never, a few times ever, once a year or so, few times per year, monthly, weekly, or daily); and self-control and awareness during and ability to recall experiences (N/A, yes, sometimes, no). It is scored by summing the seven items. A Cronbach's alpha reliability coefficient of 0.91 indicates the glossolalia questionnaire has good internal consistency.

Social status (Singh-Manoux, Adler, & Marmot, 2003), social support (Blake & McKay, 1986), exercise (Paffenbarger, Blair, Lee, & Hyde, 1993), religiosity (Rohrbaugh & Jessor, 1975), faith maturity (P. L. Benson, Donahue, & Erickson, 1993), perceived stress (S. Cohen & Williamson, 1988), education, age, sleep cycle, relationship status, and sex were self-reported as potential confounders of dissociation or stress. Of these, age, social support, exercise, and sleep cycle fulfilled criteria for inclusion in analytical models.

Procedure

To characterize stress and arousal on a religious service and non-service day, Sunday was chosen as the most active worship day of the week and Monday as the only common non-worship day for both churches. Saliva was self-sampled four times per day. Times for self-sampling were standardized as 10 a.m., 2:30 p.m., 6 p.m., and 10 p.m. for both Sunday and Monday. This "minimal protocol" (Adam & Kumari, 2009) was selected to capture diurnal cycles but avoid Sunday services, when participants were unwilling to interrupt worship to provide a sample. Predetermined times have been used by others in similar circumstances (e.g., Decker, 2000, 2006; Flinn & England, 1995; Worthman & Panter-Brick, 2008).

Saliva samples were collected using commercially available synthetic oral swabs and swab storage tubes (Salimetrics LLC, State College, PA, USA). Each participant was issued an insulated kit containing eight swab and tube sets, an ice pack, a set of questionnaires, and instructions. Participants recorded the date and time of each sample and any missed samples, then refrigerated or froze the entire kit until pickup. They were reminded by phone or text message before each sample. If a sample time was missed, they were asked to skip to the next sample or, in some cases, to take the sample when they were able and record the time. No participants missed more than two consecutive samples on a given day, which was a criterion for exclusion from data analyses. Participants completed the questionnaires during the same week they collected saliva samples. Completed kits were retrieved within a week, transported to the University at Albany, and stored in a freezer at –30° until assayed.

Biochemical analyses

Assays for cortisol and alpha-amylase were conducted at the University at Albany (Albany, NY, USA) and Salimetrics LLC (State College, PA, USA) using commercially available assays (Salimetrics, LLC). Samples were thawed to room temperature beforehand and centrifuged at $1500 \times g$ for 15 min to remove mucins.

For cortisol, 25 µl of saliva was pipetted into 96-well microtitre plates pre-coated with antibodies to cortisol followed by cortisol bound to horseradish peroxidase. Tetramethylbenzidine was added to each well, and optical density (450 nm) was determined. All samples, including standard curve (0–3 µg/dl) and unknowns, were run in duplicate, and outcomes represent the average. Wells containing known high and low cortisol concentrations were used to correct for multiple plate comparisons and produced a combined lab intra-assay variation (%CV) of 5.2%. Inter-lab variation (%CE) computed for the mean of 17 replicate tests was 13.5%. Both values are considered normal for salivary cortisol analysis (Garde, Hansen, & Nikolajsen, 2003).

Alpha-amylase samples were diluted with phosphate-buffered solution containing a non-mercury preservative in a 1:200 ratio. A volume of 8 µl of diluted saliva was reacted with 320 µl of preheated (37°C) alpha-amylase substrate solution consisting of 2-chloro-*p*-nitrophenol linked with maltotriose (0.01% sodium azide added as preservative). For accurate timing, one strip was measured at a time by placing it on a kinetic mixer (550 RPM) at 37°. Optical density (450 nm) was determined via a universal microplate plate reader at 1 min and 3 min, replacing the strip on the mixer in the interim. One-minute readings were subtracted from 3-min readings and multiplied by the conversion factor, which takes the 1:20 sample dilution into

account. Results were computed in U/ml of alpha-amylase using the formula: [absorbance difference per minute × total assay volume (328 ml) × dilution factor (200)]/[millimolar absorptivity of 2-chloro-*p*-nitrophenol (12.9) × sample volume (0.008 ml) × light path (0.97)]. Wells containing high and low alpha-amylase concentrations were used to correct for multiple plate comparisons. Average intra- and inter-assay coefficients of variation were 4.1% and 8.5%, respectively. There are no data available on %CV norms for amylase.

Statistical analyses

Statistical analyses were conducted using SPSS Statistics Version 19.0 for Windows (IBM Corp., Somers, NY, USA). Analyses were considered significant when $p \leq 0.05$.

To control for the influence of overall involvement in church activities on stress (Ellison, Boardman, Williams, & Jackson, 2001) and a possible interaction effect of church involvement with glossolalia, a dummy variable was created that grouped participants by their status within the church. This was done by categorizing participants according to Williams' (1984) Pentecostal church hierarchy as elite, core, supportive, or marginal. *Elite* are church elders and the pastor's immediate adult family members; *core* include other church officers, choir members, and other attendees of multiple weekly services; *supportive* are "Sunday Christians" and *ad hoc* committee members; and *marginal* are unstable members, children, and those limited by mental or physical disability. Marginal participants in this study were "backsliders," people who have received the Holy Ghost but 'slid back' into sin. Backsliders sometimes return to the church but tend to waver in religiosity and attendance and are thus considered unstable in their membership status. Classifications were determined based on the first author's familiarity with the participants. Because of the limited sample size, status categories were further reduced to either elite/core (58%) or supportive/marginal (42%).

Because theory suggests that practice is key to the transformative influence of ritual dissociation (Luhrmann, Nusbaum, & Thisted, 2010), we chose the "lifetime glossolalia experiences" item for preliminary analyses of dissociation effects. The item was dichotomized for comparison of high- and low-glossolalists. Those experiencing 20 or fewer lifetime experiences were placed in the low glossolalia experiences (LGE) group. These individuals were either newly baptized in the Holy Spirit or had only experienced glossolalia a few times over a number of years. Those reporting 21 or more experiences (high glossolalia experiences or HGE) also reported experiencing glossolalia daily, weekly, or monthly.

Preliminary descriptives and frequencies, including mean and standard deviation (SD), were calculated for the total sample and high- and low-glossolalists for all questionnaire and biomarker variables. Outlier biomarker values ($>$ or <4 SDs from mean) were excluded, resulting in the removal of five cortisol values. These were not associated with any particular participant. Remaining cortisol concentrations were transformed ($\log_{10}$) due to typical non-normal distribution (Adam & Kumari, 2009). Alpha-amylase values were normally distributed and not transformed.

Salivary cortisol and alpha-amylase exhibit different responses to stress and arousal so multiple indices were examined. Because we were examining overall differences in HPA and SNS activity based on accumulated glossolalia experience, we used area under the curve (AUC), which summarizes the total output of the biomarker in question using data from repeated measures (Gordis, Granger, Susman,

& Trickett, 2008). Total cortisol and alpha-amylase were calculated using AUC with respect to ground (Pruessner, Kirschbaum, Meinlschmid, & Hellhammer, 2003), based on the trapezoid formula. The formula we used is summarized as

$$\sum_{i-1}^{n-1} t_i \left[m_{(i+1)} + m_i/2 \right]$$

where t_i indicates the time distance between measures, m_i the measurement, and n the total number of measures. The Sunday-to-Monday differences in AUCs and individual measures for the total sample and for the HGE relative to the LGE group were compared using the Student's t statistic.

Multivariate analyses of covariance (MANCOVA) were conducted to test both hypotheses. Bivariate correlations were used to determine variables for regression models. Independent variables were the glossolalia questionnaire or any of its items that significantly correlated with any dependent variables. Covariates were those significantly correlated with any dependent variables, except where collinear. Candidate covariates included church attended, age, sex, relationship status, education, social status, number of children, social support, sleep [an index (hours of sleep) × (quality of sleep)], perceived stress, religiosity, exercise, and church status. Church status was included to test for a potential interaction effect with glossolalia. Sunday and Monday AUCs of both biomarkers were used as dependent variables to test first and second hypotheses, respectively. Additionally, Monday models included Sunday AUCs as covariates because morning cortisol levels are predicted by stress and arousal experiences on the previous day (Adam, Hawkley, Kudielka, & Cacioppo, 2006). Because of the small sample size, multivariate tests were conducted using Pillai's Trace (Tabachnick & Fidell, 2007). Secondary univariate analyses were also conducted using Bonferroni corrections ($p = 0.025$) for multiple tests. Preliminary assumption testing was conducted for both models to check for normality, linearity, univariate and multivariate outliers, homogeneity of variance–covariance matrices, and multicollinearity. Violations of variance–covariance assumptions were dealt with by using a more conservative alpha.

Results

Socio-demographic characteristics and descriptives are detailed in Table 1 with respect to total sample and high- and low-glossolalists. High- and low-glossolalists were similar in all factors except church status ($t = -4.6$, $p < 0.001$), social support ($t = -2.6$, $p = 0.01$), religiosity ($t = -3.2$, $p = 0.002$), and glossolalia ($t = -5.4$, $p < 0.001$), which were all greater in the HGE group.

Table 2 shows the results of bivariate correlations. The glossolalia questionnaire positively correlated with Sunday cortisol (AUC), fulfilling the criterion for inclusion as an independent variable in regression models. Age and number of children were positively correlated with cortisol but found to be collinear, so only age was retained. Other covariate correlations were social support, exercise, and sleep. The study church attended correlated positively with marital status and SES and negatively with social support, suggesting some potential differences in the two study sites. Separate correlation analyses with the glossolalia questionnaire items showed the lifetime glossolalia experiences item positively correlated with Monday alpha-amylase

Table 1. Socio-demographic characteristics and psychometric descriptive for high- (HGE) and low-glossolalists (LGE).

	HGE ($n = 26$)			LGE ($n = 26$)		
	n	*x* (SD)	%	*n*	*x* (SD)	%
Age	26	32.7 (11.04)		26	33.8 (11.45)	
Females	15		57.7	12		46.2
Marital status						
Single	11		42.3	8		31.8
In a relationship	3		11.5	4		26.0
Married	12		46.2	12		46.2
Separated/divorced	0		0	2		8.0
Education						
Some high school	0		0	3		11.5
High school	4		15.4	7		26.9
Some college/trade school	11		42.3	10		38.5
Associate/trade school degree	6		23.1	2		7.7
Bachelor degree	4		15.4	2		7.7
Graduate degree	1		3.8	2		7.7
Number of children	22	1.6 (2.08)		26	1.3 (1.78)	
Social status[a]	25	5.3 (1.28)		24	4.9 (2.04)	
Partner's social status[a]	14	3.4 (1.91)		11	3.9 (2.63)	
Social support*						
0 people	0		0	1		3.8
1 person	1		3.8	1		3.8
2–5 people	9		34.6	13		50.0
6–9 people	2		7.7	8		30.8
10 or more people	14		53.8	3		11.5
Sleep[b]	26	23.3 (9.32)		26	23.9 (11.87)	
Perceived stress	26	15.7 (6.99)		26	18.8 (6.11)	
Exercise	25	17.3 (10.31)		22	14.8 (10.04)	
Glossolalia*	26	23.8 (2.75)		26	7.9 (8.90)	
Faith maturity	26	5.0 (0.93)		26	4.9 (1.34)	
Religiosity*	26	32.4 (4.03)		26	27.3 (6.86)	
Church status*						
Elite/core	22		84.6	8		30.8
Supportive/marginal	4		15.4	18		69.2
Church						
Kingston	12		46.2	11		42.3
Poughkeepsie	14		53.8	15		57.7

[a]Social status represents self-reported placement on a 10-rung ladder from highest to lowest (1–10).
[b]Sleep represents an index of hours of sleep × quality of sleep.
*$p \leq 0.05$.

($p = 0.02$), which was therefore included as an independent variable in separate regression models.

Table 3 summarizes the comparisons of mean AUCs and individual measures for the total sample and both glossolalia experience groups. In the total sample, the only significant difference between Sunday and Monday was a greater volume of

Table 2. Bivariate correlations.

	Monday cort	Sunday sAA	Monday sAA	GQ	Sex	Age	Education	Marital status	SES	Social support	Children	Church status	Church attended	PSS	RMQ	FMS	Sleep	Exercise
Sunday cort	0.70**	−0.37**	−0.25	0.27*	0.09	−0.42**	−0.16	−0.10	0.11	−0.08	−0.43**	0.10	−0.04	−0.09	0.09	0.16	−0.08	0.05
Monday cort		−0.37**	−0.24	0.05	0.10	−0.29*	−0.10	−0.07	−0.13	−0.20	−0.44**	0.02	0.05	−0.04	0.02	0.06	0.08	0.21
Sunday sAA			0.76**	0.15	0.16	−0.01	0.11	0.01	0.14	0.33*	0.03	0.12	0.10	0.07	0.17	−0.13	−0.28*	0.28*
Monday sAA				0.18	0.06	−0.12	0.14	−0.09	0.13	0.27	−0.12	0.14	0.12	0.04	0.09	−0.05	−0.18	−0.02
GQ					0.09	0.01	0.11	−0.17	0.16	0.34*	0.06	0.61**	−0.07	−0.30*	0.39**	0.15	−0.10	0.15
Sex						0.06	0.09	0.12	0.09	−0.03	0.01	−0.12	0.15	0.18	0.12	−0.03	−0.28*	−0.06
Age							0.22	0.27	−0.21	0.10	0.67**	−0.08	−0.12	−0.18	0.06	0.04	0.22	−0.26
Education								0.21	−0.21	0.14	0.11	0.16	−0.08	−0.03	0.13	−0.04	−0.24	−0.04
Marital status									−0.04	0.08	0.29*	0.07	0.31*	−0.06	−0.05	−0.05	0.13	0.04
SES										0.06	−0.16	0.01	0.28*	−0.10	0.02	−0.38**	−0.19	0.03
Social support											0.13	0.19	−0.32*	−0.36**	0.36**	0.03	0.00	0.06
Children												0.10	−0.17	0.00	0.07	0.12	0.07	−0.03
Church status													−0.06	−0.10	0.27	−0.04	−0.04	0.30*
Church attended														0.14	−0.14	−0.12	0.09	0.04
PSS															−0.14	−0.05	−0.19	0.17
RMQ																0.36**	−0.12	0.24
FMS																	0.00	0.25
Sleep																		−0.20

Note: cortisol (cort) and alpha-amylase (sAA) values are for area under the curve, GQ is glossolalia questionnaire, PSS is Perceived Stress Scale, RMQ is Religiosity Measures Questionnaire, FMS is Faith Maturity Scale, and sleep is an index of average hours-by-quality of sleep.
*$p \leq 0.05$, **$p \leq 0.01$.

alpha-amylase (AUC) on Monday. In examining the HGE group, there was a significant reduction in the cortisol AUC and at the 10 a.m. individual measure on Monday relative to Sunday. They also exhibited a significantly greater level of total alpha-amylase and alpha-amylase at 10 p.m. on Monday than on Sunday. There were no significant changes from Sunday to Monday in the LGE group.

The HGE and LGE groups were also compared on each day. On Sunday, alpha-amylase is significantly greater in the HGE group at 6 p.m., right before the evening evangelical service. On Monday, the HGE group displayed a significantly higher level of total alpha-amylase and significantly higher levels at 6 p.m. and 10 p.m. There are no significant between-group differences in cortisol for either day.

Differences between HGE and LGE for biomarkers on each day are summarized in Figure 1. The error bars indicate HGE and LGE groups have overlapping distributions. More arousal occurs in the LGE group on Monday, as illustrated by the relatively flattened diurnal alpha-amylase line, compared to that of the HGE group. Cortisol is similar in both groups on Sunday, but the HGE group displays an overall lower profile on Monday. The cortisol profile of the LGE group is relatively unchanged from Sunday to Monday.

To control for potential confounds that could affect these relationships, separate MANCOVAs were used to test these observations. Models 1 and 2 tested biomarker variations on Sunday based on the glossolalia questionnaire and lifetime glossolalia experience item, respectively, using church status, age, social support, sleep, exercise, and glossolalia questionnaire-by-church status. No violations of preliminary assumptions for multivariate tests were noted. For the combined variables in Model 1, the only statistically significant influence was age ($F_{2,26} = 7.61$, $p = 0.002$, Pillai's Trace $= 0.37$, partial eta$^2 = 0.37$). For Model 2, there was a statistically significant difference among glossolalists ($F_{12,72} = 2.77$, $p = 0.004$, Pillai's Trace $= 0.63$, partial

Table 3. Student's t comparison of salivary cortisol$_{log10}$ and alpha-amylase values and areas under the curve (AUC) with respect to high (HGE) and low (LGE) lifetime glossolalia experiences.

	Total sample ($n = 52$)		HGE ($n = 26$)		LGE ($n = 26$)	
	Sun	Mon	Sun	Mon	Sun	Mon
Cortisol (μg/dl)						
AUC	−9.86	−10.57**	−9.05††	−10.74*	−10.66	−10.39
10 a.m.	−0.65	−0.73**	−0.58	−0.75*	−0.72	−0.71
2:30 p.m.	−0.73	−0.81	−0.67	−0.80	−0.79	−0.82
6 p.m.	−0.92	−0.95	−0.82	−0.95	−1.00	−0.96
10 p.m.	−1.04	−1.08	−1.01	−1.11	−1.06	−1.05
Alpha-amylase (U/ml)						
AUC	1430.6	1592.3*	1600.6††	1840.5**†	1260.7	1344.0
10 a.m.	124.4	131.1	138.0	149.1	117.9	110.4
2:30 p.m.	119.8	129.1	130.1	137.3	105.9	117.9
6 p.m.	111.0	127.7**	129.1†	157.4†	92.9	105.1
10 p.m.	132.4	150.2	130.4	185.7*†	121.2	102.1

*$p \leq 0.05$, **$p \leq 0.10$ for difference from Sunday to Monday.
†$p \leq 0.05$, ††$p \leq 0.10$ for between-groups difference on same day.

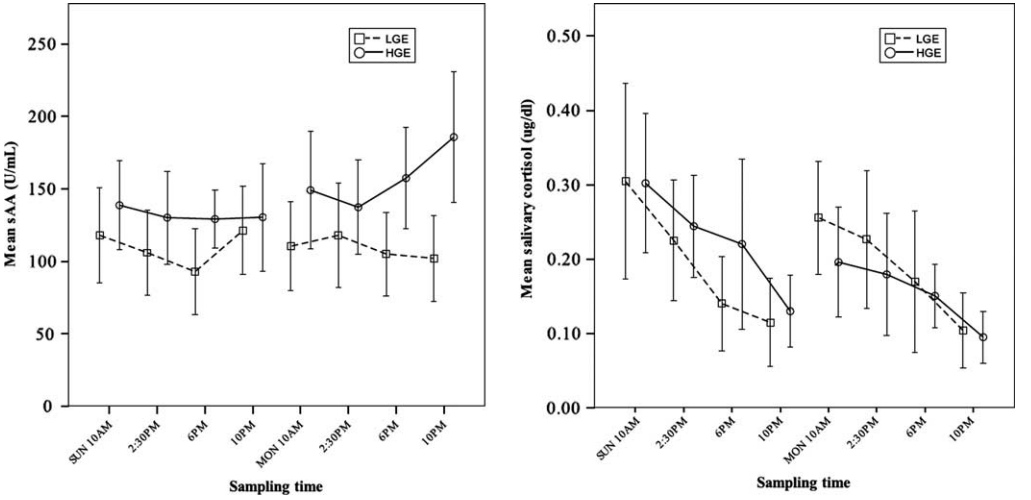

Figure 1. Mean salivary alpha-amylase (U/ml) and cortisol (μg/dl ± SEM) by sampling time and high (HGE) or low (LGE) glossolalia experience.

eta$^2 = 0.32$) and for age ($F_{2,35} = 6.75$, $p = 0.003$, Pillai's Trace $= 0.28$, partial eta$^2 = 0.28$). No significant influence was noted for church status or a glossolalia-by-church status interaction.

Univariate results were also examined with Bonferroni corrections for multiple testing. Table 4 shows these results for Sunday biomarkers using the glossolalia questionnaire (Model 1) and lifetime glossolalia experience (Model 2). A Bonferroni adjusted alpha level of 0.025 was used for cortisol while a more conservative alpha of 0.0125 was used for alpha-amylase due to a violation of the equal variance assumption. These models indicate the influence of age is on cortisol (Model 1: $F_{1,27} = 14.64$, $p = 0.001$, partial eta$^2 = 0.35$; Model 2: $F_{1,36} = 11.14$, $p = 0.002$, partial eta$^2 = 0.24$). No other results were significant.

Models 3 and 4 tested the effects of the glossolalia questionnaire and lifetime glossolalia experience, respectively, on Monday cortisol and alpha-amylase measures while controlling for Sunday AUCs, age, social support, sleep, and church status. Preliminary assumption testing revealed no violations. For the Model 3 multivariate test, there were significant influences and notable effect sizes of glossolalia ($F_{30,50} = 1.89$, $p = 0.02$, Pillai's Trace $= 1.06$, partial eta$^2 = 0.53$), cortisol ($F_{2,24} = 19.62$, $p = 0.000$, Pillai's Trace $= 0.62$, partial eta$^2 = 0.62$), and alpha-amylase ($F_{2,24} = 13.06$, $p = 0.000$, Pillai's Trace $= 0.52$, partial eta$^2 = 0.52$). The Model 4 multivariate test indicates significant influences but smaller effect sizes (except for the Sunday biomarker influences) of lifetime glossolalia experience ($F_{12,68} = 3.19$, $p = 0.001$, Pillai's Trace $= 0.72$, partial eta$^2 = 0.36$), church status ($F_{2,33} = 4.91$, $p = 0.01$, Pillai's Trace $= 0.23$, partial eta$^2 = 0.23$), age ($F_{2,33} = 4.46$, $p = 0.02$, Pillai's Trace $= 0.21$, partial eta$^2 = 0.21$), exercise ($F_{2,33} = 4.95$, $p = 0.01$, Pillai's Trace $= 0.23$, partial eta$^2 = 0.23$), cortisol ($F_{2,33} = 23.49$, $p = 0.000$, Pillai's Trace $= 0.59$, partial eta$^2 = 0.59$), alpha-amylase ($F_{2,33} = 20.19$, $p = 0.000$, Pillai's Trace $= 0.55$, partial eta$^2 = 0.55$), and a lifetime glossolalia experience-by-church status interaction ($F_{8,68} = 3.71$, $p = 0.001$, Pillai's Trace $= 0.61$, partial eta$^2 = 0.30$).

Table 5 shows the univariate tests for Models 3 and 4 using a Bonferroni adjusted alpha of 0.025. Significant effects on Monday cortisol AUC were noted in Model 3 for the glossolalia questionnaire ($F_{15,25} = 2.94$, $p = 0.01$, partial eta$^2 = 0.64$) and Sunday cortisol ($F_{1,25} = 40.50$, $p = 0.000$, partial eta$^2 = 0.62$) and a significant though smaller effect size for social support ($F_{1,25} = 5.92$, $p = 0.02$, partial eta$^2 = 0.19$). Only Sunday alpha-amylase was a significant influence on Monday alpha-amylase measures ($F_{1,25} = 27.00$, $p = 0.000$, partial eta$^2 = 0.52$). Model 4 indicates significant influences on Monday cortisol of lifetime glossolalia experience ($F_{6,34} = 3.42$, $p = 0.01$, partial eta$^2 = 0.38$), church status ($F_{1,34} = 3.42$, $p = 0.01$, partial eta$^2 = 0.18$), Sunday cortisol ($F_{1,34} = 39.56$, $p = 0.000$, partial eta$^2 = 0.54$), and a lifetime glossolalia experience-by-church status interaction ($F_{4,34} = 5.74$, $p = 0.001$, partial eta$^2 = 0.40$). Significant effects were noted on Monday alpha-amylase for lifetime glossolalia experience ($F_{6,34} = 3.00$, $p = 0.02$, partial eta$^2 = 0.35$), age ($F_{1,34} = 9.18$, $p = 0.01$, partial eta$^2 = 0.21$), and Sunday alpha-amylase ($F_{1,34} = 31.79$, $p = 0.00$, partial eta$^2 = 0.48$).

Discussion

This study tested the predictions that (1) biomarkers of stress and arousal on a service day would be the same for all Apostolic Pentecostals, and (2) there would be

Table 4. Univariate regression models predicting Sunday salivary cortisol (cort) and alpha-amylase (sAA) areas under the square (AUC) from age, social support, sleep, church status, glossolalia, and church status-by-glossolalia interactions.

	DV	d.f.	*F*	*p*	Partial eta^2
Model 1	cort AUC[a]	24	1.94	0.05	0.63
	sAA AUC[b]	24	1.12	0.39	0.50
Glossolalia questionnaire	cort AUC	15	2.10	0.05	0.54
	sAA AUC	15	0.79	0.68	0.30
Social support	cort AUC	1	0.47	0.50	0.02
	sAA AUC	1	0.83	0.37	0.03
Age	cort AUC	1	14.64	0.001	0.35
	sAA AUC	1	0.40	0.54	0.01
Sleep	cort AUC	1	0.12	0.74	0.004
	sAA AUC	1	0.39	0.54	0.01
Exercise	cort AUC	1	2.45	0.13	0.08
	sAA AUC	1	0.89	0.11	0.09
Church status	cort AUC	1	0.10	0.74	0.01
	sAA AUC	1	0.37	0.55	0.01
Church status × glossolalia questionnaire	cort AUC	4	1.49	0.12	0.18
	sAA AUC	4	1.64	0.19	0.20
Model 2	cort AUC[c]	15	1.87	0.06	0.44
	sAA AUC[d]	15	2.10	0.03	0.47
Lifetime glossolalia experience	cort AUC	6	2.59	0.03	0.30
	sAA AUC	6	2.76	0.03	0.32
Social support	cort AUC	1	1.65	0.21	0.04
	sAA AUC	1	3.70	0.63	0.09
Age	cort AUC	1	11.14	0.002	0.24
	sAA AUC	1	0.03	0.86	0.001
Sleep	cort AUC	1	0.27	0.61	0.01
	sAA AUC	1	4.06	0.05	0.10
Exercise	cort AUC	1	0.04	0.84	0.001
	sAA AUC	1	3.82	0.06	0.10
Church status	cort AUC	1	1.88	0.18	0.05
	sAA AUC	1	5.80	0.02	0.14
Church status × lifetime glossolalia experience	cort AUC	4	0.56	0.70	0.06
	sAA AUC	4	2.43	0.07	0.21

Note: glossolalia questionnaire represents the sum of eight items, including lifetime glossolalia experience; average glossolalia duration and frequency; and general recall of, and self-awareness and self-control during glossolalia experiences. Lifetime glossolalia experience represents an ordinal scale (0, 1–5, 6–10, 11–20, 21–50, 51–100, >100).
[a]$r^2 = 0.60$, [b]$r^2 = 0.48$, [c]$r^2 = 0.44$, [d]$r^2 = 0.41$.

subsequent indications of reduced stress in those biomarkers on a non-service day among Pentecostals with greater glossolalia experience. The results affirm both predictions, though biomarkers are uniformly higher among the high-glossolalists on Sunday. Both groups displayed overlapping distributions, suggesting there were active and inactive individuals in both groups. On Monday, high-glossolalists showed stress and arousal reductions not evident in low-glossolalists.

Table 5. Univariate regression models predicting Monday salivary cortisol (cort) and alpha-amylase (sAA) areas under the curve (AUC) from Sunday AUCs, age, social support, sleep, church status, glossolalia, and church status-by-glossolalia interactions.

	DV	d.f.	*F*	*p*	Partial eta^2
Model 3	cort AUC[a]	26	5.26	0.000	0.85
	sAA AUC[b]	26	3.24	0.002	0.77
Sunday cort AUC	cort AUC	1	40.50	0.000	0.62
	sAA AUC	1	0.24	0.63	0.01
Sunday sAA AUC	cort AUC	1	0.16	0.70	0.01
	sAA AUC	1	26.95	0.000	0.52
Glossolalia questionnaire	cort AUC	15	2.94	0.01	0.64
	sAA AUC	15	1.24	0.31	0.43
Social support	cort AUC	1	5.92	0.02	0.19
	sAA AUC	1	0.01	0.91	0.000
Age	cort AUC	1	0.84	0.37	0.03
	sAA AUC	1	1.37	0.25	0.05
Sleep	cort AUC	1	0.26	0.61	0.01
	sAA AUC	1	0.043	0.52	0.02
Exercise	cort AUC	1	0.46	0.51	0.02
	sAA AUC	1	0.18	0.67	0.01
Church status	cort AUC	1	2.79	0.11	0.10
	sAA AUC	1	0.62	0.44	0.02
Church status × glossolalia questionnaire	cort AUC	4	1.36	0.28	0.18
	sAA AUC	4	0.26	0.90	0.04
Model 4	cort AUC[c]	17	7.63	0.000	0.79
	sAA AUC[d]	17	6.09	0.000	0.75
Sunday cort AUC	cort AUC	1	39.56	0.000	0.54
	sAA AUC	1	2.31	0.14	0.06
Sunday sAA AUC	cort AUC	1	3.30	0.08	0.09
	sAA AUC	1	31.79	0.000	0.48
Lifetime glossolalia experience	cort AUC	6	3.42	0.01	0.38
	sAA AUC	6	3.00	0.02	0.35
Social support	cort AUC	1	0.71	0.41	0.02
	sAA AUC	1	0.01	0.92	0.000
Age	cort AUC	1	0.62	0.44	0.02
	sAA AUC	1	9.18	0.01	0.21
Sleep	cort AUC	1	0.12	0.73	0.004
	sAA AUC	1	0.13	0.72	0.004
Exercise	cort AUC	1	8.19	0.01	0.19
	sAA AUC	1	0.56	0.50	0.02
Church status	cort AUC	1	7.42	0.01	0.18
	sAA AUC	1	1.001	0.32	0.03
Church status × lifetime glossolalia experience	cort AUC	4	5.74	0.001	0.40
	sAA AUC	4	2.33	0.08	0.22

[a]$r^2 = 0.84$, [b]$r^2 = 0.77$, [c]$r^2 = 0.74$, [d]$r^2 = 0.75$.

Limitations and strengths

Conclusions should be tempered with respect to the limited sample size and medium-to-small effect sizes for some of the regression results (J. Cohen, 1992). This is especially true for the church status-by-glossolalia interactions, which, though statistically significant with regard to cortisol in Model 4, are not robust findings. Larger magnitude differences would have been possible with an approximately one-third increase in sample size. The extent to which Sunday biomarker levels are due to religious activities is also unclear, but could have been controlled for had it been possible to collect Saturday "pre-test" samples and might have resulted in a larger effect size. Also, though alternative cut-points for grouping glossolalia experiences were explored, methods for quantifying these and investigation of the greater glossolalia variance among the low-glossolalists require further research. Other methods of measuring dissociation could have been used (Luhrmann, 2005), but we opted against these to limit participant burden. Future work should include detailed data regarding diet and other non-worship activities that may influence stress (Adam & Kumari, 2009) and psychological factors that may affect religious dissociation (Luhrmann et al., 2010). Finally, Bosch, Veerman, de Geus, and Proctor (2011) recently suggested, contrary to Rohleder, Wolf, Maldonado, and Kirschbaum (2006), that the saliva collection procedures used may limit the validity of alpha-amylase results.

Importantly, our data support the model that a lifetime of ritual dissociative practice may be adaptive in reducing overall stress load (Goodman, 1972; Ludwig, 1983; Lynn, 2005; Schumaker, 1991, 1995) and validate research indicating religious and spiritual behavior (Dedert et al., 2004; Ironson et al., 2002; Lynn et al., 2010; Mihaljević et al., 2011; Tartaro, Luecken, & Gunn, 2005) and meditative approaches (Carlson, Speca, Patel, & Goodey, 2004; Lee, Lee, Kim, & Moon, 2003; MacLean et al., 1997; Park et al., 2007; Sudsuang, Chentanez, & Veluvan, 1991; Yeager et al., 2006) may buffer neuroendocrine consequences of stress. A recent brain imaging study of glossolalists suggests how this might occur (Newberg, Wintering, Morgan, & Waldman, 2006). A reduction in prefrontal cortical activity while dissociating may influence reduced self-oriented thinking. Such thinking is associated with the arousal of worrying that leads to psychosocial stress. In our study, high-glossolalists showed up to church and emphatically prayed more often than low-glossolalists. This emphatic prayer is often a whole body kinesis toward the desired result of glossolalia. Thus, the practice of praying out loud and emphasis on achieving glossolalia may combine to focus one's mind away from stressful worldly things and produce a "relaxation response" (H. Benson & Klipper, 2000).

Comparison of models using the glossolalia questionnaire versus the lifetime glossolalia experiences item affirms this. The questionnaire, which includes the dissociative items, was associated with a nearly two-fold greater effect on both Sunday and Monday cortisol levels than the lifetime glossolalia experiences item, which is essentially a time factor. The HPA axis, which cortisol represents, is more associated with chronic stress or produces a delayed response in bioassays, while the SNS, represented by alpha-amylase, is more associated with the immediate arousal or "adrenaline rush." While this does not preclude an effect of dissociative practice on arousal, it supports an influence on long-term psychosocial stress, which can have lasting implications for health, as chronic stress has been associated with hippocampal neuron death (Sapolsky, 2002).

Finally, this work is the first "neurotheology" study to examine stress biomarker profiles among Charismatics in a naturalistic setting and provides a model for the study of culturally situated dissociation (cf. Newberg et al., 2006; Pavelsky, 1975; Philipchalk & Mueller, 2000). It thereby contributes to the cultural neuroscience of dissociation by integrating the "psychiatric-adaptive" and "anthropological-discursive" models of dissociation (Seligman & Kirmayer, 2008). It supports recent findings using a similar approach, that internet gaming may both increase and reduce stress via dissociation (Snodgrass, Lacy, Francois Dengah, Fagan, & Most, 2011), and affirms links detected between dissociation and religious ritual (Dorahy, Schumaker, Krishnamurthy, & Kumar, 1997; Dorahy & Lewis, 2001).

Conclusion

This study examined a specific mechanism whereby religion is held to influence health. Two main findings emerged: (1) glossolalia was associated with overall elevations in cortisol and alpha-amylase, biomarker of stress and arousal, respectively, on the day of religious service irrespective of one's role in the church, which is likely due to the high activity levels of Pentecostal worship; (2) high-glossolalists exhibit lower stress and arousal loads on the non-service day, which appear to be significantly related to glossolalia and status within the church. Glossolalia is an embodied pattern of religious behavior with biological outcomes. Among the implications of those outcomes may be the reduction or prevention of biological stress for those with more experience with culturally-mediated dissociation. Biomarkers represent one dimension of the interaction of such behavior and stress; this work must therefore be taken as preliminary work that provides a tangible foundation for further investigation.

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Appendix 1. Glossolalia questionnaire

Following is the full glossolalia questionnaire as administered. Items 2, 3, 4, 9, 10, 11, and 12 are the seven items that comprise the scale. Several of the additional items were used to query about unacceptable glossolalia, as discussed elsewhere (Lynn, n.d.).

1. How old were you the first time you spoke in tongues? _____

2. How many times have you spoken in tongues? (circle one)
   0
   1–5
   6–10
   11–20
   21–50
   51–100
   101 +

3. How frequently do you speak in tongues? (circle one)
   Never
   A few times ever
   Once a year or so
   Few times per year
   Monthly
   Weekly
   Daily

4. How long do your tongue-speaking experiences last ON AVERAGE? (circle one)
   Never spoken in tongues
   Less than 10 seconds
   10–30 seconds
   1–5 minutes
   5–15 minutes
   15–30 minutes
   More than 30 minutes

5. How long was your shortest tongue-speaking experience? Please indicate the unit of time in your answer – e.g., seconds or minutes or hours. Indicate 0 if you have never spoken in tongues.
   _____

6. How long was your longest tongue-speaking experience? Please indicate the unit of time – e.g., seconds or minutes or hours. Indicate 0 if you have never spoken in tongues.
   _____

7. Have you ever faked speaking in tongues? (circle one)
   Never spoken in tongues
   No
   Yes

8. Some report having been the "battleground" of demons and the Holy Ghost before their Baptism of the Holy Spirit. Have you ever spoken in tongues as the devil or a demon, or have you only been filled with the Holy Ghost? (circle one)
   Never spoken in tongues
   Demon/devil only
   Both Holy Ghost and demon
   Holy Ghost only

9. Are you aware of your thoughts while you speak in tongues? (circle one)
   Never spoken in tongues
   No
   Sometimes
   Yes

10. Can you control your body while you speak in tongues? (circle one)
   Never spoken in tongues
   No
   Sometimes
   Yes

11. Do you fully remember the experience of speaking in tongues?
   Never spoken in tongues
   No
   Sometimes
   Yes

12. How would you rate your tongue-speaking experiences in intensity ON AVERAGE?
   Never spoken in tongues
   Not intense at all
   Not very intense
   Neutral
   Somewhat intense
   Very intense
   Extremely intense

13. There seem to be several types of speaking in tongues that might be observable. These include a calm, private experience of the Holy Ghost that cohabits with your mind and may occur anywhere; an excited, public experience of the Holy Ghost that seems to displace your mind and occurs more often in church; the tongues of demons battling the Holy Ghost for possession of a person; the tongues of those who believe they have the Holy Ghost but are being tricked by the devil; and the tongues of those who are faking receiving the Holy Ghost for whatever reason. Please indicate any of these forms that you personally have experienced in your own spiritual journey.
   Holy Ghost-calm
   Holy Ghost-excited
   Demons/devil battling Holy Ghost
   Demons/devil tricking person into believing they have Holy Ghost
   Faked Holy Ghost

14. How do you feel after speaking in tongues? Circle one answer for each of the following two columns.

Very bad	Exhausted
Bad	Tired
Somewhat bad	Somewhat tired
Neutral	Neutral
Somewhat good	Somewhat stimulated
Good	Stimulated
Very good	Very stimulated

15. In the space below, please describe your most memorable tongue-speaking experience in your own words.