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HEART-RATE VARIABILITY AS A QUANTITATIVE MEASURE OF HYPNOTIC DEPTH

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Abstract: The authors investigated whether heart-rate variability can serve as a device for real-time quantitative measurement of hypnotic depth. This study compared the continuous self-rated hypnotic depth (SRHD) of 10 volunteers with heart rate, amplitude, and frequency changes from a time-frequency analysis of heart-rate variability (HRV). The authors found significant linear relationships between SRHD and the high-frequency (HF) component of HRV. Specifically, SRHD was correlated negatively with the frequency of the HF component and positively with the amplitude of the HF component. Unexpectedly, the average temporal trend in SRHD fit well (R^2 = .99) to the step response of a first-order system with a 4-minute time constant. The findings suggest that the reactivity of the parasympathetic branch of the autonomic nervous system reflected in HRV could become part of a real-time, quantitative measure of hypnotic depth.

One of the major challenges in hypnosis research is to assure sufficient depth to induce genuine hypnotic responsiveness (Barabasz & Christensen, 2006). Hypnotic depth is thus a dynamic property that represents a subject's momentary capacity for response to hypnotic suggestions. This is distinct from hypnotic susceptibility, which is a

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stationary characteristic of the subject (Shor & Orne, 1962; Weitzenhoffer & Hilgard, 1959, 1962). The American Psychological Association definition of hypnosis states that the induction of hypnosis is generally inferred when a subject responds to hypnotic suggestions (Green, Barabasz, Barrett, & Montgomery, 2005). An alternative approach would be to infer hypnotic depth from the neurophysiological dynamics that are associated with hypnosis. Our long-term aim is to develop a hypnometer, a device for measuring hypnotic depth based on continuously monitored physiology.

A candidate for monitoring neural activity during hypnosis is EEG. Highly hypnotizable subjects show greater EEG asymmetry and higher power over the parietal region in the theta, alpha, and beta frequency bands, which are associated with sustained-attentional processing (Crawford, Clarke, & Kitner-Triolo, 1996). A wide variety of EEG changes have been observed during hypnotic analgesia (De Pascalis & Perrone, 1996), recall of emotional events (De Pascalis, Ray, Tranquillo, & D'Amico, 1998), and imagination of aversive stimuli (Gemignani et al., 2000). Although measuring neural activity with EEG for a hypnometer is a promising research direction, we choose first to explore the less complex effects of hypnosis on the autonomic nervous system.

A measure of the autonomic nervous system (ANS) response to hypnosis can be obtained from heart-rate variability (HRV), which is a time series of pulse intervals. HRV contains low-frequency (LF, 0.04–0.15 Hz) oscillations that result from both sympathetic and parasympathetic activity and high-frequency (HF, 0.15–0.4 Hz) oscillations associated mainly with parasympathetic stimulation through the vagus nerve. The latter is related to respiratory influences and is thus often called the respiratory sinus arrhythmia (RSA) (Camm et al., 1996). A number of prior studies have examined these aspects of HRV during hypnosis (De Pascalis & Carboni, 1997; Debenedittis, Cigada, Bianchi, Signorini, & Cerutti, 1994; Gemignani et al., 2000) and meditation (Peng et al., 2004; Peng et al., 1999) and have found increases both in total power and in HF power relative to LF power, suggesting a shift in the ANS toward parasympathetic control. These reports of changes in HRV during hypnosis are not explained by hypnotizability (Ray et al., 2000). Therefore, we hypothesize that time-frequency analysis of HRV within a hypnosis session will reflect autonomic changes during hypnosis that offer a measure of hypnotic depth.

In the present study, time-frequency analysis is used to study the LF and HF components of HRV, and we observe overall changes in LF and HF amplitude during hypnosis as expected. Moreover, estimating the dominant frequency of the LF and HF components revealed a downward frequency shift in the HF component. Our significant new finding is that heart rate, HF frequency, and HF amplitude, estimated with the time-frequency analysis, correlate with the dynamic self-rating of hypnotic depth (SRHD). These results provide a basis for future experimentation on continuous, quantitative measurement of hypnotic depth. We discuss our findings in the context of understanding of the nature of hypnosis and furthering its use in the clinic.

METHOD

Subjects

Ten healthy adult subjects (4 male, 6 female, mean age 21) participated in this institutional-review-board-(IRB) approved pilot study. Eligibility required hypnotizability, which we defined as an induction score of at least 6 (on a 0 to 12 scale) and a profile score of at least 3 (on a 0 to 5 scale) on the Hypnotic Induction Profile (Spiegel & Spiegel, 1978). Additional exclusion criteria were a history of psychological disorders, trauma, current cardiac or health problems, and intake of medications at the time of the experiment.

Control Condition

During the 10-minute control condition, subjects were instructed to sit comfortably and to relax with their eyes closed while listening to the experimenter and—to keep subjects awake and focused—to determine whether a series of statements were true or false. The statements had minimal emotional content and required only common knowledge, such as "bicycles have two wheels." Subjects indicated their responses by moving a lever that would be used later to indicate hypnotic depth.

Hypnosis Condition

During the 10-minute hypnosis condition, subjects were instructed to sit comfortably with their eyes closed while listening to the same experimenter. A progressive relaxation induction was used (Hammond, 1998), along with deepening suggestions of increased awareness of any physical sensations that accompany hypnosis. Further suggestions were given for the subjects to take a "mental vacation" to a pleasant location such as a warm, sunny beach, and subjects were encouraged to focus on imagined sights, sounds, and feelings. Subjects were instructed (and subsequently reminded every 1 to 2 minutes) to move a lever to indicate how hypnotized they felt on a continuous scale of 0 to 5 over the course of the experiment and to move the lever any time a change was perceived in hypnotic depth. The lever position provided our measure of SRHD.

The control condition was always conducted prior to the hypnosis condition, because it was anticipated that the lasting effects of hypnosis would confound the experiment more than the nonrandomized order of conditions.

Deriving the Heart-Rate Variability Signal

HRV can refer to either the oscillations in pulse interval or its reciprocal (Camm et al., 1996). Pulse interval was selected for the analysis because efferent vagal stimulation has a linear relationship with pulse interval and a hyperbolic relationship with heart rate (Parker, Celler, Potter, & McCloskey, 1984).

Electrocardiogram (ECG) was measured with a three-lead clinical patient monitor (78354A, Hewlett-Packard, Palo Alto, CA) and sampled at 200 Hz with a 12-bit analog-to-digital converter (NI DAQPad-6020E, National Instruments Corp., Austin, TX). All subsequent data analysis was performed with MATLAB (The MathWorks, Inc., Natick, MA). A matched-filter beat detection algorithm was used to determine the beat times in the ECG record. A clean heartbeat cycle in the ECG record for each subject was manually selected and used as the detection kernel. The kernel was correlated over time with the subject's entire ECG record, producing a time-varying correlation coefficient. The local correlation peaks were fit by least squares to a parabola, and the beat times were estimated by solving for a local maximum in the parabola's curve. Differences between beat times were taken to obtain the interbeat interval (IBI) series.

It was also necessary to correct for false beat detection due to motion artifacts in the ECG record by replacing outlying data points with the values from a 10-point median filter on the original IBI data. The percentage of corrected pulse intervals was below 2% on all subjects. Also, the natural sampling rate of the HRV signal is irregular due to the variation in beat times. All HRV data were consequently resampled to a regular 3 Hz time base using a piecewise cubic spline interpolation prior to signal analysis.

Statistical Analysis of Heart-Rate Variability

Three types of signal analyses were performed on the HRV data. (1) A basic mean and standard deviation were calculated directly from the HRV to examine overall properties of the HRV data during the control and hypnosis conditions. (2) The power was measured in four frequency bands of a filter bank (below 0.04 Hz [VLF], between 0.04 and 0.15 Hz [LF], between 0.15 and 0.40 Hz [HF], and above 0.40 Hz [residual]) that correspond to accepted physiological divisions (Camm et al., 1996). This facilitates comparisons with prior hypnosis-HRV literature. (3) Time-frequency analysis was performed with a windowed autoregressive method. This analysis estimates the frequency and amplitude of the HF and LF components localized in time for correlation with other dynamic data sources like SRHD.

For the filter bank, fourth-order digital infinite impulse response (IIR) filters were used. The filters were designed by the Butterworth method because the frequency response is maximally flat in the pass band (Kay, 1988). We then computed the root-mean square (RMS) amplitude to facilitate comparisons with the subsequent time-frequency analysis. The time-frequency analysis was performed with the total least squares (TLS), modified covariance method of autoregressive (AR) frequency estimation, chosen for its unbiased frequency estimates with low computational demand and robustness to noise (Kay). The data records were divided into 30-second periods, without overlap, to examine the time-varying statistical properties of the HRV data.

The AR frequency estimation mathematics that we applied can be summarized in a few equations. Our first step was to compute the mean of the HRV signal in each 30-second period to obtain a time-varying estimate of heart rate. We then subtracted these mean values so that the HRV signal in the periods was distributed about zero. We then fit a mathematical model to each 30-second period of HRV data, which is the sum of two sinusoids with added noise:

$$x[n] = a_{\mathrm{LF}} \sin(2\pi f_{\mathrm{LF}} n + \varphi_{\mathrm{LF}}) + a_{\mathrm{HF}} \sin(2\pi f_{\mathrm{HF}} n + \varphi_{\mathrm{HF}}) + \varepsilon[n], \qquad (1)$$

where x is the zero-mean HRV signal at interpolated point n, a is amplitude, f is frequency in Hz, φ is phase angle, ε is assumed to be Gaussian white noise, and the HF and LF subscripts indicate the low- and high-frequency components. Based on AR theory, the model in Equation 1 can be equivalently described by the fourth-order AR process:

$$\begin{aligned} x[n] = x[n] = &-bx[n-k] - cx[n-2k] \\ &- bx[n-3k] - x[n-4k] + \varepsilon[n], \end{aligned} \qquad (2)$$

where

$$b = -2\cos(2\pi f_{\mathrm{LF}} k) - 2\cos(2\pi f_{\mathrm{HF}} k) \qquad (3)$$

and

$$c = 4\cos(2\pi f_{\mathrm{LF}} k)\cos(2\pi f_{\mathrm{HF}} k) + 2 \qquad (4)$$

and k is a time lag constant. Unbiased frequency estimates can be obtained with Equation 2 by varying the coefficients b and c to minimize the normalized sum-of-squares quantity:

$$\sum_{n=4k}^{N} \left(\frac{x[n-4k] + bx[n-3k] + cx[n-2k] + bx[n-k] + x[n]}{\sqrt{c^2 + 2b^2 + 2}} \right)^2, \qquad (5)$$

where N is the number of time points in the data period. The values of b and c that minimize equation 5 can be computed efficiently by singular value decomposition or eigenanalysis (Kay, 1988). The frequency estimates are then calculated by inverting equations 3 and 4:

$$\hat{f}_{\mathrm{LF}} = \frac{1}{2\pi k}\arccos\left(\frac{-b-\sqrt{b^2+8-4c}}{4}\right) \tag{6}$$

$$\hat{f}_{\mathrm{HF}} = \frac{1}{2\pi k}\arccos\left(\frac{-b+\sqrt{b^2+8-4c}}{4}\right). \tag{7}$$

While it is mathematically possible for certain values of the coefficients b and c to yield imaginary frequency estimates, this rarely occurs in practice with estimates from a 30-second HRV period. Once the frequencies are estimated, then the amplitude of the two components can be estimated by a linear regression of sine and cosine components at those frequencies by minimizing the sum of squares error:

$$\sum_{n=1}^{N}\left(\begin{matrix} d\sin\left(2\pi\hat{f}_{\mathrm{LF}}k\right)+e\cos\left(2\pi\hat{f}_{\mathrm{LF}}k\right)+g\sin\left(2\pi\hat{f}_{\mathrm{HF}}k\right) \\ +h\cos\left(2\pi\hat{f}_{\mathrm{HF}}k\right)-x[n] \end{matrix}\right)^2, \tag{8}$$

where d, e, g, and h are coefficients that are varied to minimize Equation 8. The amplitude estimates $\hat{a}$ for the two components are:

$$\hat{a}_{\mathrm{LF}} = \sqrt{d^2+e^2} \tag{9}$$

and

$$\hat{a}_{\mathrm{HF}} = \sqrt{g^2+h^2}. \tag{10}$$

For our analysis, we used a lag time k of 2, which, together with the 3 Hz sampling rate, enables the AR model to distinguish frequencies up to 0.75 Hz unambiguously. This frequency range is sufficient to model the typical HRV signal components that are normally found below 0.4 Hz and can model higher frequency noise carried by a heart rate of up to 90 beats per minute. The maximum heart rate of all subjects in this study remained below this threshold.

Correlating HRV Statistics with Self-Rated Hypnotic Depth

The subjects used a lever to report SRHD during the 10-minute hypnosis condition. The lever position was digitized at 200 Hz simultaneously with recording the ECG data. The lever-position data were normalized by the maximum rating reported by each subject so that a value of one indicates the highest reported hypnotic depth for a subject. The mean normalized SRHD was calculated for each 30-second period.

We normalized the frequency, amplitude, and mean HRV estimates from the hypnosis condition by dividing each parameter by the mean value from the control condition for each subject. The normalized parameter values from all 30-second periods and from the 10 subjects were pooled. This resulted in a total of 200 data points for SRHD and the five dynamic parameters (mean heart rate, LF, and HF frequencies and amplitudes).

The SRHD data were then divided into five bins of equal count with 40 measurements per bin. Coarse binning removes the inherent temporal correlations that can confound the analysis and enhances the clarity of graphical representations of the results. A linear regression was performed between binned mean SRHD and the corresponding mean AR parameters.

RESULTS

Both the mean and standard deviation in IBI increased during hypnosis reflecting a decrease in average heart rate and greater variability. The HF component decreased in frequency and increased in amplitude during the hypnosis condition, while the LF component increased in amplitude. The residual decreased in amplitude, suggesting the presence of a relationship between hypnosis and higher order HRV components. SRHD showed a trend of increasing over time and was negatively correlated with the frequency of the HF component and positively correlated with HF amplitude.

Interbeat Interval and Amplitude

The overall changes in HRV that occurred during hypnosis are shown in Figure 1. Panel (a) shows the mean and standard deviation normalized by the control condition values, indicating the relative changes in HRV during the hypnotic state. This normalization scheme controls for individual differences and facilitates a group comparison. Prior to normalization, the mean control condition IBI across subjects was 861 ms (± 55.4 ms) and for the hypnosis condition the mean IBI

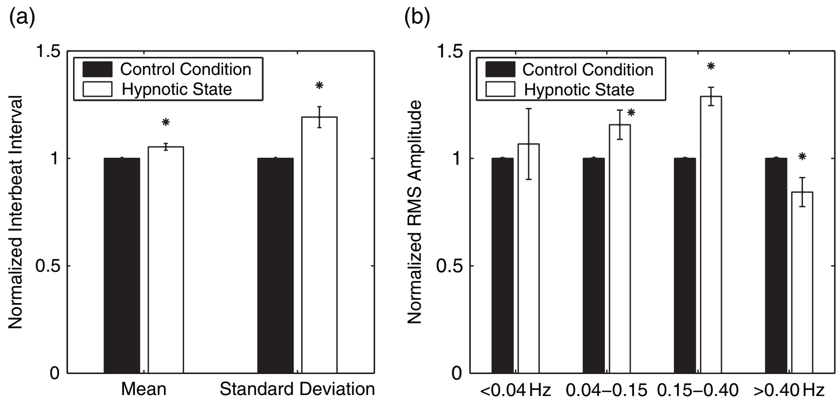

Figure 1. **Differences in the interbeat-interval (IBI) signal during hypnosis compared with the control condition. All values were normalized by the control condition results. Error bars are standard error (*n* = 10). Values were compared with a one-sample, two-tailed *t* test. Significant differences (*p* < .05) between the hypnosis and control condition are indicated by *. (a) Mean and standard deviation of IBI within each session. (b) Root-mean square (RMS) amplitude in the indicated bands of the filter bank.**

was 909 ms (± 68.9 ms). All reported values prior to normalization are in normal physiological ranges.

Panel (b) of Figure 1 shows the results of the filter bank analysis. All values are shown relative to the control condition RMS amplitude. The average control condition amplitudes of IBI oscillations in the respective frequency bands prior to normalization were 33.8, 33.3, 29.3, and 9.7 ms in order (VLF, LF, HF, residual). The average hypnosis condition amplitudes in the respective frequency bands were 32.9, 38.9, 38.5, and 7.8 ms. The largest increase in RMS amplitude was by 26.8% in the HF band (0.15 to 0.40 Hz).

Autoregressive Time-Frequency Analysis

Parameters calculated with the AR analysis are shown in Figure 2. The mean values of the parameters for each subject, normalized by the results from the control condition, were used in this comparison, resulting in $n = 10$ for each parameter. The average control-condition heart rate was 70.3 beats per minute (bpm); this value is not statistically different from the estimate of 69.7 bpm made directly from the IBI data, $t(9) = 0.36$, $p = .73$. The respective mean frequency values for the LF and HF components prior to normalization were 0.11 and 0.32 Hz for the control and 0.11 and 0.29 Hz for the hypnosis condition. The

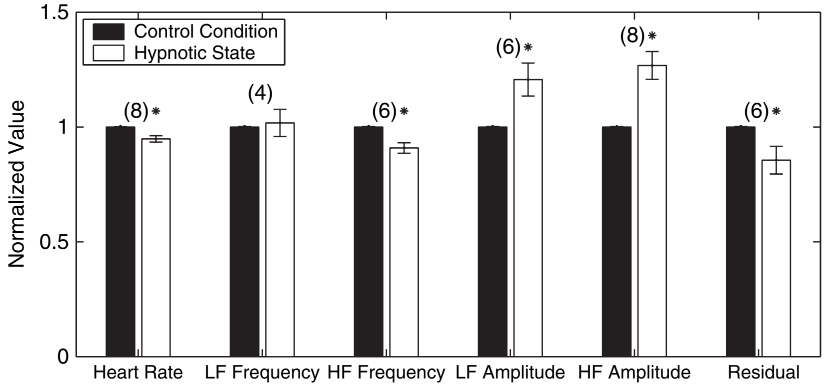

Figure 2. **Mean AR parameter differences between the hypnosis condition and the control condition. Error bars are standard error (*n* = 10). Group differences were tested with a one-sample, two-tailed *t* test. Significance (*p* < .05) is indicated by *. Within-subject tests were also performed from parameters estimated from 30-second periods of data with a two-sample, two-tailed *t* test. The numbers in parentheses indicate how many subjects out of 10 had significant individual differences (*p* < .05).**

corresponding amplitudes of IBI oscillations were 40.4 and 23.5 ms for control and 49.5 and 29.8 ms for hypnosis. The residual amplitudes for control and hypnosis were 7.6 and 6.5 ms.

The significant group differences (criterion $\alpha = 0.05$) during hypnosis compared to control were a decrease in heart rate, a decrease in the frequency of the HF component, and an increase in the corresponding amplitude. There was also a significant increase in the LF component's amplitude and a decrease in the residual amplitude during hypnosis. These differences are similar to those found in the overall differences reported in Figure 1.

Self-Rated Hypnotic Depth Analysis

An increasing temporal trend was found in the mean SRHD as shown in Figure 3a. The rate of increase in hypnotic depth appeared to slow over time, so we fit the data to the functional form of a unit-step input response for a first-order system,

$$z(t) = u(t) - e^{-t/\tau}, \tag{11}$$

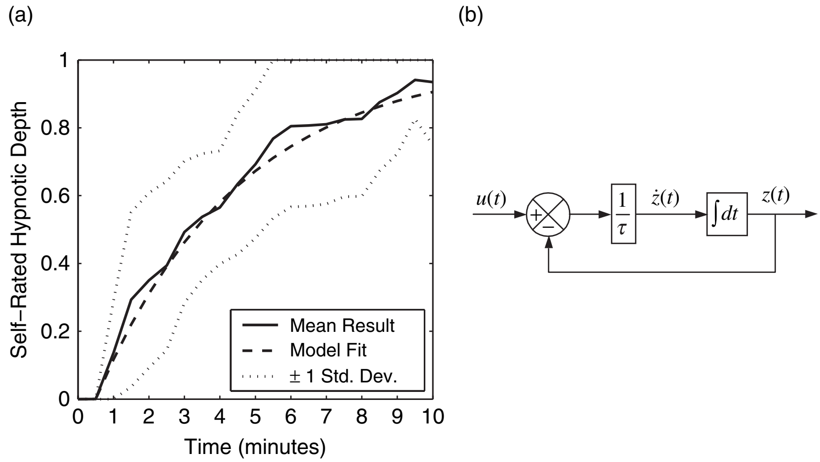

Figure 3. **Temporal trend in self-rated hypnotic depth during the hypnosis sessions. (a) The solid line shows the mean normalized lever position used by the subjects to indicate trance depth (SRHD). The dotted lines show the standard deviation range across the 10 subjects. The goodness-of-fit with unit-step response to a first-order dynamical system (Equation 11) is highly significant, $F(1, 18) = 285.35$, $R^2 = .99$, $p < .001$, with a time constant $\tau = 4.03$ minutes. (b) A block diagram for the dynamical system model. The variable *u* represents the hypnotic stimulus and *z* represents hypnotic depth.**

where u is the hypnotic stimulus ($u = 1$ for $t > 0$), z denotes hypnotic depth, τ is the system time constant, and t is time. In Figure 3b, we show the block diagram for the corresponding first-order system.

The result of the linear correlation between the parameters of the AR analysis and SRHD is shown in Figure 4. Heart rate was negatively correlated with SRHD, such that heart rate tended to be lower when subjects felt more deeply hypnotized. The frequency of the HF component was also negatively correlated with the SRHD, while the HF amplitude was positively correlated. Other parameters did not correlate significantly with SRHD.

Discussion

Heart-Rate Variability and Self-Rated Hypnotic Depth

The results of the AR analysis support our initial hypothesis that time-frequency analysis of HRV within a hypnosis session offers a measure of hypnotic depth. Specifically, our new findings are that heart rate and HF frequency are negatively correlated and HF

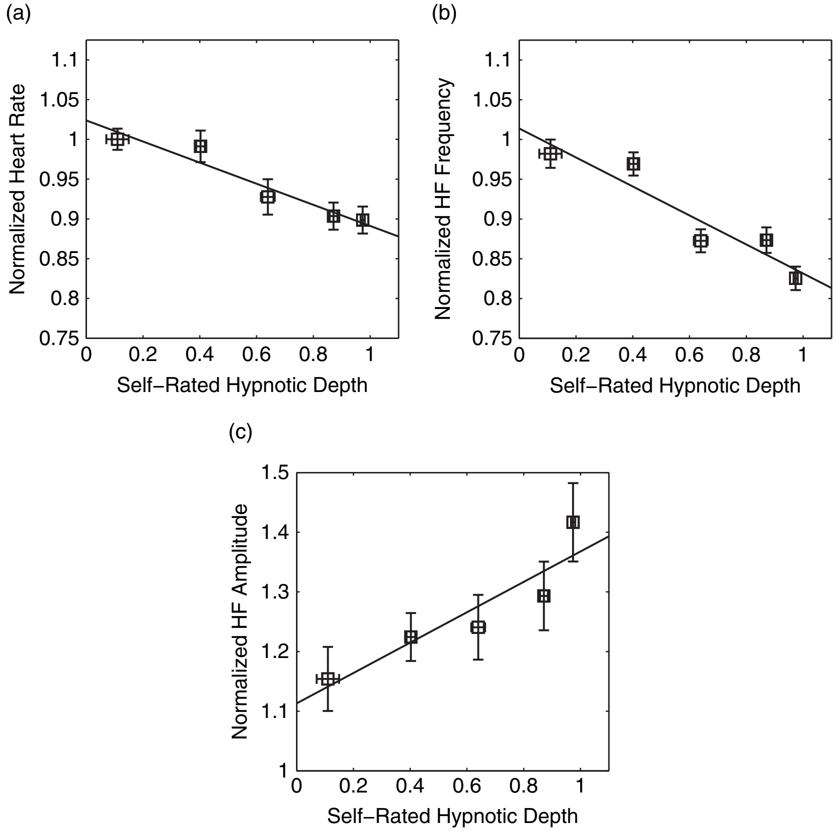

Figure 4. **Correlation between self-rated hypnotic depth and three of the AR parameters derived from HRV data. Forty measurements are included in each bin. The error bars show the standard error. The significance of the correlations was determined with a F test (n = 5). (a) Negative correlation (slope = –0.13) between SRHD and mean heart rate, $F(1, 3) = 38.84$, $R^2 = 0.91$, $p < .05$. (b) Negative correlation (slope = -0.18) with HF frequency, $F(1, 3) = 24.26$, $R^2 = 0.89$, $p < .05$. (c) Positive correlation (slope = –0.25) with HF amplitude, $F(1, 3) = 15.22$, $R^2 = 0.83$, $p < .05$.**

amplitude is positively correlated with SRHD. The overall changes we observed in HRV are generally consistent with other reports in the hypnosis-HRV literature (De Pascalis & Carboni, 1997; Debenedittis et al., 1994; Gemignani et al., 2000).

Although we found significant overall correlations between heart rate, HF amplitude, HF frequency, and SRHD, the relationships were not fully consistent across all subjects (Figure 2). While small sample size may be a factor, there are several other possibilities, such as the variation being analogous to the significant individual variation found in hypnotizability (Shor & Orne, 1963; Weitzenhoffer & Hilgard, 1962). Prior experience with hypnosis may also play a role, as suggested by training effects in hypnosis (Bates, Miller, Cross, & Brigham, 1988). There is also the possibility that, as with meditation, extensive experience may alter neural activity (Lutz, Greischar, Rawlings, Ricard, & Davidson, 2004) and brain structure (Lazar et al., 2005), and these differences may alter the relationships between physiology and cognitive states. Alternately, novice subjects might have failed to report significant changes because the experience did not match their preconceived notions of hypnosis (Green, 2003). False self-reporting could also confound our study because subjects may have perceived an expectation to report a positive experience with hypnosis to please the experimenter (Silva, Bridges, & Metzger, 2005).

An Unexpected Finding: A Temporal Trend in SRHD

An unexpected finding was that the temporal trend in mean SRHD fit very well ($R^2 = .99$) to the unit-step response of a first-order dynamical system with a 4-minute time constant (Figure 3). This suggests that the model accurately describes the average psychophysiological hypnotic response of our subjects, reflective either of our specific experimental conditions or an inherent property of the cognitive state change that occurs during hypnosis. The governing equation for the model expressed in Figure 3b could be used to predict hypnotic depth changes to a dynamic hypnotic input $u(t)$ to test the model's validity.

Though we used a constant hypnotic suggestion as input, the nonlinear dynamics in SRHD do show the subjects' responsiveness, insofar as we would expect a linear trend if they were just moving the lever on the presumption that depth simply increases over time. But, contrary to the smooth average trend in SRHD, we believe that hypnotic depth undergoes some slight fluctuations from moment to moment as is thought to occur in meditation (Lazar et al., 2000; Lutz et al., 2004). Fluctuations in hypnotic depth may have been unnoticed or unreported, especially by subjects who were inexperienced with hypnosis. Future studies could use varied suggestions and require that subjects report hypnotic-depth changes with higher frequency.

In terms of contemporary hypnosis theories, the first-order dynamical system might be viewed as an analog of the executive ego in neodissociation theory (Hilgard, 1977). In this analogy, the time constant characterizes the dynamics of the executive ego's response to suggestions. One way to explore the validity of this analogy is to test whether degree of dissociation, as assessed with randomized painful stimuli or amnesic suggestions, correlates with the dynamics of hypnotic depth measured from HRV.

Physiology of Heart-Rate Variability and Hypnosis

The downward frequency shift we observed in the HF component of HRV probably resulted from a lower spontaneous respiration rate during hypnosis, since HF frequency in HRV correlates well ($R^2 = .88$) with respiration rate (Thayer, Sollers, Ruiz-Padial, & Vila, 2002). Spontaneous decreases in respiration rate are also known to result from meditation (Lazar et al., 2000) and from changes in arousal (Shea, 1996). As a result, the use of HRV to measure hypnotic depth should be cross-referenced with other measurement modalities for the purposes of developing a hypnometer.

The decreased residual amplitude during hypnosis in the AR analysis indicates that the two-sinusoid model was a better fit for the HRV signal during hypnosis compared to control. This finding suggests that the higher order physiological dynamics decrease during hypnosis. As such, higher order and nonlinear dynamical models of the HRV signal may explain some additional variance and provide greater insight into the autonomic effects of hypnosis.

Limitations of the Study

The psychometric applicability of this study remains limited because our measure of hypnotic depth comes solely from self-reports of the subjects (SRHD). This SRHD metric was also normalized by the maximum reported value for each subject, which could be problematic in other experimental contexts. The subjects in this study served as their own controls for the analysis of average HRV statistics. Given that the induction involved suggestions for relaxation and the HRV changes are consistent with a decrease in physiological arousal, there is ambiguity in whether the changes are specifically related to the hypnotic state. While this confound also exists in the time-frequency analysis, the correlations between dynamics in the HRV and SRHD indicate that the effect is more than a single physiological shift that occurred during the induction. Another confound is the possibility that subjects entered active-alert or spontaneous hypnosis during the control condition (Barabasz, 2006), which would prevent a clear interpretation of how the average HRV changes relate to hypnosis. The time-frequency analysis is not subject to this limitation because it makes use of only the hypnosis-condition data. Further studies in this area could probe for physiological changes that are consistent during both relaxed and active-alert hypnosis. It would also be beneficial to control for experimenter bias, hypnotizability, and age-related changes in HRV. Although the lack of control in these areas limits the conclusions that can be drawn from this study, the results motivate further investigation of the physiological dynamics related to hypnotic depth.

Future Applications

The long-term aim of this research is to obtain a device capable of indicating hypnotic depth based on continuously monitored physiology. The results of the present study represent a small step forward in this regard that will help inform future investigations. While HRV provides some helpful insights, it will be necessary to include other physiological measurements to acquire a more complete picture. Nonetheless, in a controlled environment, our findings could supply supplementary metrics for research on, for example, hypnotic analgesia (De Pascalis & Perrone, 1996; Feldman, 2004; Rainville, Carrier, Hofbauer, Bushnell, & Duncan, 1999). A broader picture of hypnosis may also be obtained from dynamic physiological models of systemic and cerebral hemodynamic physiology from near-infrared spectroscopy (NIRS) (Diamond et al., 2005). It is also technically feasible to simultaneously record EEG and NIRS (Ehlis, Ringel, Plichta, Hermann, & Fallgatter, 2005; Strangman et al., 2001), and the combined measurements enable, for example, spatially localized cross-correlations between alpha activity and concentration changes of deoxygenated hemoglobin (Moosmann et al., 2003), which could be further correlated with SRHD. We anticipate that combined EEG and NIRS coupled with HRV analysis will ultimately be the preferred instrument for real-time measurement of hypnotic depth—the hypnometer.

The therapeutic applications of a hypnometer are primarily instances where hypnotic responsiveness is essential, such as with nonpharmacological analgesia (Lang et al., 2000; Schupp, Berbaum, Berbaum, & Lang, 2005). By using such a device, a practitioner could ascertain hypnotic depth in a patient or client quickly and either use additional deepening suggestions or proceed with confidence. Other applications are to investigate the relationship between hypnotic depth and the efficacy of suggestions, and to cross validate theories that explain hypnotic phenomena. Given its potential to increase understanding of the relationship between hypnosis and physiology, to assess hypnotic interventions, and to examine the nature of hypnosis, a hypnometer would serve as an enabling technology for research and would help propel hypnosis into the mainstream clinical arena.

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Herzfrequenzvariabiliät as quantitatives Maß der Hypnosetiefe

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Zusammenfassung: Die Autoren untersuchten, ob Herzfrequenzvariabilität als Indikator für die momentane Hypnosetiefe geeignet ist. Im Rahmen dieser Untersuchung wurden die selbst berichtete Hypnosetiefe von 10 Teilnehmern zu Herzfrequenz, Amplitude sowie Frequenzveränderungen

im Rahmen einer Zeit-Frequenz-Analyse der Herzfrequenzvariabilität (HRV) in Bezug gesetzt. Es zeigten sich signifikante Zusammenhänge zwischen der berichteten Hypnosetiefe und die Hochfrequenzkomponente (HF) der HRV. Insbesondere ergab sich, dass die selbst berichtete Hypnosetiefe negativ mit der HF-Frequenz und positiv mit der HF-Amplitude korrelierte. Unerwarteterweise stimmte der durchschnittliche zeitliche Trend der Hypnosetiefe gut mit der Stufenantwort eines first-order-system mit 4-minütiger Zeitkonstante überein (R^2 = .99). Die Befunde legen nahe, dass die Reaktivität des parasympathischen Teils des autonomen Nervensystems, angezeigt durch die HRV, als quantitativer Indikator der Hypnosetiefe eingesetzt werden könnte.

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La variabilité de la fréquence cardiaque en tant que mesure quantitative de la profondeur de l'état hypnotique

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Résumé: Les auteurs ont cherché à savoir si la variabilité de la fréquence cardiaque pouvait servir d'outil de mesure quantitative en temps réel de la profondeur de l'état hypnotique. Cette étude a comparé la profondeur continue de l'état hypnotique autocotée (PEHA) de 10 volontaires avec des écarts relatifs au rythme cardiaque, à l'amplitude et à la fréquence, tirés d'une analyse temps/fréquence de la variabilité de la fréquence cardiaque (VFC). Les auteurs ont trouvé une relation linéaire significative entre la PEHA et la composante haute fréquence (HF) de la VFC. Plus particulièrement, la PEHA montrait une corrélation négative avec une haute fréquence, et une corrélation positive avec une amplitude de faute fréquence. Contre toute attente, la tendance temporelle moyenne dans la PEHA correspond bien (R^2 = 0,99) à la réponse transitoire d'un système de premier niveau avec une constante de temps de quatre minutes. Ces résultats indiquent que la réactivité de la voie parasympathique du système nerveux autonome, tel que refétée par la VFC, pourrait bien devenir une mesure quantitative, en temps réel, de la profondeur de l'état hypnotique.

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Variabilidad de la tasa cardíaca como una medida cuantitativa de profundidad hipnótica

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Resumen: Los autores investigaron si la variabilidad de la tasa cardíaca puede servir como un dispositivo contemporáneo de medición cuantitativa de la profundidad hipnótica. Este estudio comparó la profundidad hipnótica informada continuamente (SRHD) de 10 voluntarios con la tasa cardíaca, amplitud, y cambios de frecuencia de un análisis en el dominio temporal de la variabilidad de la tasa cardíaca (HRV). Los autores encontraron relaciones

significativas lineales entre el SRHD y el componente de alta-frecuencia (HF) de la HRV. Específicamente, el SRHD correlacionó negativamente con la frecuencia de la HF y positivamente con la amplitud de la HF. Inesperadamente, el promedio de la tendencia temporal del SRHD se ajustó bien ($R2$ = .99) a la respuesta gradual de un sistema de primer-orden con una constante de 4 minutos. Los resultados sugieren que la reactividad de la rama parasimpática del sistema nervioso autónomo, reflejada en la HRV, podría convertirse en parte de una medida cuantitativa contemporánea de la profundidad hipnótica.

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