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The emotional and physiological structure of laughter: A comparison of three kinds of laughs (Antiphonal, Duchenne, and Voiced) and individual differences in the use of laughter in middle-aged and older marriages

by

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A dissertation submitted in partial satisfaction of the

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Committee in charge:

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The emotional and physiological structure of laughter: A comparison of three kinds of laughs (Antiphonal, Duchenne, and Voiced) and individual differences in the use of laughter in middle-aged and older marriages

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Abstract

The emotional and physiological structure of laughter: A comparison of three kinds of laughs (Antiphonal, Duchenne, and Voiced) and individual differences in the use of laughter in middle-aged and older marriages

by

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Doctor of Philosophy in Psychology

University of California, Berkeley

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In close relationships, laughter plays an important role in attachment maintenance, communication, and emotion regulation. We know from previous research that laughter, particularly in response to watching humorous film clips, is associated with increased positive emotion (Ruch, 1995), increased cardiovascular and electrodermal arousal, including heart rate, respiration rate, and skin conductance (Marci, Moran, et al. 2004), and decreased arterial stiffness--indicated by longer pulse transmission times (Vlachopoulos, Xaplanteris, et al. 2009). We do not know, however, much about the time course of these changes, how these changes persist following laughs, and whether these changes will also be found in more naturalistic and more emotionally varied settings (i.e., middle-age and older couple conversations about marital conflict). It is also unclear whether previous research findings associating laughter with emotional and physiological changes in arousal are dependent on the kinds of laughs involved. Previous research has tended to pool all laughs into a single category; however, recent research has demonstrated compelling evidence that laughter is a highly complex and diverse phenomenon (e.g., Smoski & Bachorowski, 2003; Keltner & Bonanno, 1997)

In the present study, laughter was investigated using a previously collected dataset (Levenson & Carstensen, 1993) that included a sample of 156 middle-aged (40-50 yrs, N=82) and older (60-70 yrs, N=74) married couples who engaged in 15-minute videotaped discussions of conflict. Physiological arousal (heart rate inter-beat interval, skin conductance, finger temperature, finger pulse amplitude, finger pulse transit time, ear pulse transit time, and general somatic activity) was measured continuously for both spouses throughout each discussion. Also, in the original study, couples returned to the laboratory within one week following the conflict discussion to watch a videotape of themselves while using a simple rating dial (1-extremely negative to 9-extremely positive) to continuously indicate how they had been feeling throughout the original discussion. The videotapes, physiological arousal data, self-reported emotion data, as well as demographic and questionnaire data (two measures of marital satisfaction)

collected during the previous study were used in the present study. A team of trained raters coded the videotapes for the different kinds of laughs investigated. Physiological arousal data and self-reported emotion data were first averaged on a second-by-second basis and then, for each laugh, into three epochs: (a) 10-seconds before the laugh, (b) during the laugh, and (c) 10-seconds following the laugh.

Three aims were pursued in this study, (Aim #1) to determine how self-reported emotion and physiological arousal change during laughs, (Aim #2) to determine the impact of different kinds of laughs (Antiphonal, Duchenne, and Voiced) on emotional experience and physiological arousal, and (Aim #3) to determine individual differences in the use of laughter based on sex, age, and marital satisfaction.

Analyses for Aim #1 revealed: (a) laughter was associated with self-reported emotion becoming more positive during and following laughs, (b) laughter was associated with physiological arousal increases (Inter-beat Interval, Skin Conductance, and Somatic Activity) and decreases (Finger Pulse Transit Time and Ear Pulse Transit Time) during laughs. Analyses for Aim #2 revealed: (c) self-reported emotion became more positive during and following Antiphonal, Duchenne, and Voiced laughs compared to non-Antiphonal, non-Duchenne, and non-Voiced laughs, respectively, (d) Antiphonal, Duchenne, and Voiced laughs were also found to have greater physiological arousal (somatic activity and inter-beat interval) during laughs than non-Antiphonal, non-Duchenne, and non-Voiced laughs, respectively, and (e) Antiphonal laughs were found to have greater skin conductance arousal during laughs than non-Antiphonal laughs. Analysis for Aim #3 revealed: (f) middle-aged couples laughed more than older couples; and (g) satisfied couples laughed more than unsatisfied couples with middle-aged satisfied couples primarily contributing to these differences, (h) no differences in the use of laughter were found between husbands and wives, (i) older couples used proportionately more Duchenne and Voiced laughs than middle-aged couples; however, (j) middle-aged couples used proportionately more Antiphonal laughs than older couples, (k) satisfied couples used proportionately more Duchenne and Voiced laughs than unsatisfied couples, and (l) no differences between satisfied and unsatisfied couples were found in the use of Antiphonal laughter. The implications of these findings for laughter, aging, and marital research were discussed.

The emotional and physiological structure of laughter: A comparison of three kinds of laughs (Antiphonal, Duchenne, and Voiced) and individual differences in the use of laughter in middle-aged and older marriages

The emotional and physiological structure of laughter is not well understood. Previous research has associated laughter with increased positive emotion (Bachorowski & Owren, 2001), as well as both increased physiological arousal--heart rate, respiration rate, and skin conductance (Ruch, 1995; Marci, Moran, et al. 2004)--and decreased physiological arousal--pulse wave velocity, which is a measure of the speed by which blood moves through arteries in the body (Vlachopoulos, Xaplanteris, et al. 2009). What is not well understood is the temporal unfolding of these emotional and physiological changes associated with laughter, how these changes persist following laughs, and whether these changes are shared by different kinds of laughs.

The majority of previous research investigating emotional experience and physiological arousal associated with laughter has tended to pool all laughs into a single category, overlooking the rich diversity of laughs that exist and the wide range of functions they serve. In fact, laughter is a complex behavior display that takes widely varied forms. For example, two spouses recounting an amusing story from their child's upbringing may share joyous and heart-felt laughter; whereas, a spouse vehemently defending himself/herself against accusations of infidelity may express more of a contemptuous or dismissive laugh. It follows that such different kinds of laughs may have different emotional, physiological, and interpersonal consequences. In recent years, researchers have begun investigating different kinds of laughs, finding that laughs differ in morphology (Bachorowski, Smoski, et al. 2001) and in terms of whether they accompany truly felt emotion or mere social displays (Keltner & Bonanno, 1997). When laughs accompany truly felt emotion, the emotions can be both positive (e.g., amusement, exhilaration, and joy; Askenasy, 1987; Rush, 1993) and negative (e.g., anxiety, belligerence, and contempt; Gottman, 1996).

Previous research has typically investigated laughter in the context of subjects watching humorous film clips (Vlachopoulos, 2009). Therefore, little is known about laughter in more naturalistic and interpersonal contexts such as marital discussions of conflict. Finally, previous research has not investigated whether spouses use laughter differently based on individual differences in sex, age, and marital satisfaction. In the present study, I investigated laughter in the context of middle-aged and older married couples discussions of marital conflict. Specifically, I determined the emotional and physiological profile of laughter, compared the emotional and physiological impact of different kinds of laughs (Antiphonal vs. non-Antiphonal, Duchenne vs. non-Duchenne, and Voiced vs. non-Voiced), and determined differences in laughter based on sex, age, and marital satisfaction.

The origins of laughter

Laughter is believed to have evolved from the open mouth panting display of the great apes (e.g., chimpanzees and barbary macaques), characterized by a widely opened mouth and quick staccato breathing -- sharp breaths occurring in rapid succession (Darwin, 1872). In juvenile primates, the open mouth panting display is associated with

mock fighting and rough-and-tumble play (Van Hooff, 1972). The highly stereotyped nature of the display makes laughter easily identifiable. Laughter is believed to have different phylogenetic roots than smiling, which is thought to have come from the raised-lip submission and appeasement gestures of non-human primates (Lockard, Fahrenbruch, et al. 1977). Theorists have reasoned that the ultimate bases for laughter (i.e., why it became genetically selected) is that it reinforces social activities (e.g., rough and tumble play) that facilitate skill development related to social and physical intimacy, which increases reproductive fitness (Preuschoft, 1992).

What is laughter?

Present in all human cultures, laughter is a highly common and highly social behavioral display program that is deeply intertwined with emotion. Laughter has an easily identifiable communication signal characterized by a series of quick exhalations of air—on average, the duration of these blasts is 1/15th of a second separated by 1/5 of a second pauses--accompanied by either vocal chord based singsong like sounds, non-vocal chord related sounds (e.g., grunts, snorts, and whistles), breathy sounds, or no sound at all (Bachorowski & Owren, 2001).

The majority of previous research has focused on laughs associated with humor and exhilaration, which are characterized by an open mouth with raised corners (contraction of the zygomatic major muscle), relaxation of body posture, motor inhibition, and shaking of the head and torso (Ruch, 1993; Overeem, et. al., 2004). There are, however, myriad kinds of laughs, many of which look and sound very different from one another (e.g., joyous laughter vs. contemptuous laughter). Few kinds of laughs have been investigated by previous research. Notable exceptions include: antiphonal laughter, which is laughter that occurs in direct response to the laughter of another person (Smoski, 2005); voiced laughter, which is laughter that engages the vocal chords and has a singsong like sound quality (Bachorowski, 2001); and Duchenne laughter, which is laughter that is accompanied by the contraction of the orbicularis oculi muscles surrounding the eyes (Keltner & Bonanno, 1997). Also, research on teasing by Oveis, Liu, Kogan, & Keltner (in prep) found that socially dominant laughs are higher and more variable in pitch, last longer, and are louder than submissive laughs.

The proximate causes of laughter are varied. Predominantly a social behavior—laughter is 30 times more likely to occur in the company of others than when one is alone (Kuiper & Martin, 1998). Laughter is also highly contagious, such that being exposed to laughter makes it much more likely a person will laugh (Provine, 2001). Laughter may accompany genuinely felt emotions, or may be used as a mere social display (Keltner & Bonanno, 1997). Laughter may be initiated volitionally or laughter may be the non-volitional result of tickling (Harris, 1999), positive emotion (e.g., joy, humor, exhilaration, surprise, and relief; Ruch, 1995), and negative emotion (e.g., contempt, belligerence, and anxiety; Gottman, 1996). A review of previous research investigating the neural correlates of laughter, including laughter pathology (e.g., gelastic epilepsy) and brain lesion research, using a broad range of research techniques, including brain stimulation (e.g., EEG) and imaging (fMRI), found that volitional and non-volitional laughs involve partially independent neuronal pathways in the brain, suggesting they may have evolved to serve different evolutionary functions (Wild, Rodden, et al. 2003).

Specifically, the non-volitional (or emotionally driven) pathway involves the amygdala, thalamic/hypothalamic and subthalamic areas and the dorsal/tegmental brainstem. The volitional pathway originates in the premotor/frontal opercular areas and leads through the motor cortex and pyramidal tract to the ventral brainstem.

The measurement of laughter

Historically, most laughter research has simply observed whether any kind of laugh has occurred. When studies have differentiated between kinds of laughs, they have typically based such decisions on acoustic characteristics (i.e., pitch, tempo, volume, and duration) and whether or not laughs overlap, either using instruments designed to measure acoustic structures or trained behavior coders. Instrument based approaches for measuring acoustic qualities of laughter include the measurement of fundamental frequency characteristics and spectral analysis – techniques that measure sound wave characteristics in voiced laughs (Bachorowski, Smoski, et al. 2001). These approaches have uncovered rich variability of sound structures within laughs and between laughers, suggesting that people may be highly identifiable by their laughs (Bachorowski, Smoski, et al. 2001). Oveis and colleagues (in prep) trained a team of behavior coders to rate pitch, pitch variability, tempo, volume, and duration of laughs and related these characteristics to patterns of social submission and social dominance.

Another strategy for differentiating between kinds of laughs is for trained behavior coders to make judgments about the emotions that accompany laughter. Research by Keltner and Bonanno (1997), for example, used behavior coders trained in the Facial Action Coding System (FACS; Ekman, 1975)—an anatomically based coding system for measuring movements of the face associated with expressions of emotions—to measure Duchenne laughter. Duchenne laughter includes the contraction of the orbicularis oculi muscles surrounding the eyes and is believed to be an indication of genuinely felt positive emotion.

In the present study, I made use of both coding approaches (structural characteristics and co-occurring emotions) to gain a more comprehensive understanding of laughter. Specifically, trained behavior coders measured structural characteristics of laughs that have a theoretical basis for being associated with positive interpersonal communication patterns (antiphonal and voiced); and trained behavior coders measured positive emotions co-occurring with laughs, using FACS (Ekman, 1975) to identify Duchenne (positive emotions) and non-Duchenne laughs (neutral or negative emotion).

The functions of laughter

As in primates, laughter in humans continues to serve the purpose of initiating and reinforcing adolescent social play behaviors that facilitate social development and reproductive fitness. In humans, however, laughter has been co-opted to serve a broad range of additional developmental and social functions throughout the lifespan. Beginning within months of birth, laughter associated with tickling reinforces neural development involved with differentiating between self and other (Sroufe, 1972) and laughter associated with amusement and humor facilitates learning by reinforcing activities that expose us to developmentally relevant challenges (e.g., laughter during

peek-a-boo play facilitating learning of object permanence in infants; Provine, 2001). In children, laughter provides a powerful catalyst for the development and maintenance of parent/child attachments (Sroufe, 1972). In adults, laughter is used to help create psychological distance from distressful events, such as physical pain (Zweyer, Velker, et al. 2004) and feelings of loss associated with bereavement (Keltner & Bonanno, 1997).

Laughter is primarily a social behavior and previous research has found six ways in which laughter may be used to facilitate interpersonal communication. First, it may be used to communicate a wide range of emotional states, including joy, amusement, affection, anxiety, contempt, belligerence, and defensiveness (Gottman, 1996). Second, it may communicate shared positive regard and openness to continued communication (Smoski, 2005). Third, laughter may be used to instill positive emotions in others (Bachorowski & Owren, 2001), which may increase the positive associations others have with us, increase how enjoyable it is for others to talk with us, and increase how receptive others are to the messages we communicate. Fourth, because it is inherently pleasurable to laugh, making others laugh, either via the contagiousness of laughter, the use of humor, or the use of other positive emotions (e.g., joy and affection), instills positive emotions in others. Fifth, laughter may be used to communicate desirable qualities, such as social and sexual interest, intelligence, and sense of humor, as well as cognitive flexibility, and positive emotionality (Provine, 2001). Sixth, laughter may be used to communicate social hierarchy, including social dominance and social submission (Keltner & Bonanno, 1997).

The majority of previous research on the effects of laughter has not differentiated between kinds of laughs. There have been exceptions, however. First, research by Bachorowski and Owren (2001) found that the kind of laughter vocalization influences how much positive emotion is instilled in others. Specifically, laughs that engage vocal chords and make a singsong like sound were found to instill more positive emotions in others than silent laughs, laughs with a breathing sound, or laughs characterized by whistles or grunts. We know from previous research that positive emotion is an important ingredient in interpersonal communication quality (Gottman and Levenson 2000); therefore, voiced laughs may play an important role in facilitating interpersonal communication, and other kinds of positive laughs may, as well.

Second, research by Smoski (2005) found that, in the context of dyadic interactions with friends and with strangers, laughter that overlaps with (or occurs in direct response to) another's laughter (i.e., antiphonal laughter) is indicative of social bonds and is believed to communicate shared positive regard for one another and openness to continued communication. Specifically, friend dyads had higher levels of antiphonal laughter than stranger dyads, and the amount of antiphonal laughter was predictive of self-report ratings of friendship strength. Therefore, antiphonal laughter may be associated with increases in interpersonal communication quality, and so may other kinds of positive laughs.

Although laughter has not been studied in the context of marriage, previous research has found strong associations between interpersonal communication patterns and marital satisfaction (Levenson, Carstensen, et al. 1993). Taken together, these findings suggest that antiphonal laughs and voiced laughs (and possibly other forms of positive laughs, such as Duchenne laughs) are associated with interpersonal communication patterns that facilitate relationships. It follows that antiphonal laughter and voiced

laughter in the context of marriage may be associated with more satisfied relationships than less interpersonally facilitating kinds of laughs, such as non-antiphonal and non-voiced laughs.

The impact of laughter on emotion

Although laughter clearly has close ties with emotion, we know little about how laughter changes the prevailing emotional state (i.e., how emotional experience differs before vs. after a particular kind of laugh). Presently, only two studies have investigated the associations between laughs and emotion. First, a study by Keltner and Bonanno (1997) investigated Duchenne laughter when recently bereaved adults were interviewed about their loss. The study found that at the time of the interview (within six months of the spouse's death) amount of Duchenne laughter (rather than overall amount of laughter) was associated with reduced grief symptoms as well as depression and anxiety from loss. Specifically, they found that people with relatively high frequencies of Duchenne laughter had self-reported lower levels of anger, and higher levels of enjoyment, dissociation from distress, and improved social relations than people with low frequencies of Duchenne laughter.

Second, a study by Bachorowski and Owren (2001) found that the voiced quality of a laugh is predictive of the pleasantness and the degree of positive emotion it instills in others. Voiced laughs (laughs that engage the vocal chords and have a sing-song like sound quality), compared to breathy, silent, and non-voiced audible laughs (such as grunts, snorts, and whistles) are most pleasing to the ear and instill the most positive emotion in others. Non-voiced audible laughs are relatively unpleasant to the ear and instill the least positive emotion in others, compared to voiced, breathy, and silent laughs. These findings demonstrate that kinds of laughs differ in how much positive emotion they evoke in others. In addition to voiced laughs, other positive laughs (e.g., Duchenne) may also serve to instill positive emotions in others.

Taken together these research findings suggest that Duchenne laughs (laughs that involve the contraction of the muscles surrounding the eyes) and voiced laughs (laughs that engage the vocal chords and have a sing-song like quality), but not non-Duchenne laughs and non-voiced laughs, are associated with increases in positive emotion and decreases in negative emotion. Whether these findings translate to marital discussions of conflict has not been investigated.

The impact of laughter on physiological arousal

We know from previous research that during certain kinds of laughs, such as exhilaration and amusement, physiological arousal increases, including heart rate, respiration rate, and skin conductance (Ruch 1995; Marci, Moran, et al. 2004). Also, shared laughter causes more physiological arousal (skin conductance) than individual laughter (Marci et al., 2004).

In a recent study, Vlachopoulos and colleagues (2009) found that laughter in response to watching humorous film clips was associated with decreases in carotid-femoral pulse wave velocity (PWV)—a measure of how quickly a pulse travels a specified distance in the body calculated from the measurement of pulse transit time

taken at two sites (at the base of the neck for the common carotid and at the right femoral artery) and the distance between them. PWV is an index of arterial stiffness that increases as arteries become stiffer and decreases as they become more supple. This study found that changes in PWV associated with laughter persisted up to half an hour after laughs ended. High arterial stiffness is a marker of cardiovascular disease and hypertension (Blacher, Asmar, Djane, & London, 1999), and it has been associated with clinical depression and mental stress (Yeragani, Tancer, & Seema, 2006).

Positive emotions, such as amusement and contentment, have been found to undo physiological arousal associated with negative emotions, restoring physiological equilibrium (Fredrickson & Levenson, 1998). At its root, laughter is intimately intertwined with positive emotions, especially amusement. Therefore, laughter associated with positive emotion may also undo physiological arousal associated with negative emotions. Previous research involving participants watching humorous and tragic films found that physiological arousal returned to baseline (pre-film, sitting quietly levels of arousal) more quickly following humorous films than tragic films, despite laughter causing more overall arousal (Sokichi-Sakuragi, 2002). Because laughter was not measured in these studies, however, it is unclear whether laughter or something else (e.g., the experience of amusement) was responsible for the hastened return to physiological baseline. Thus, the notions that laughter restores physiological equilibrium and physiological arousal motivates laughter to reduce tension were investigated in the present study.

Although we have some understanding of the physiological correlates of laughter while watching film clips, we know very little about how these changes unfold over time (i.e., before, during, and following laughs), whether these changes differ as a function of the kinds of laughs involved, and whether these same patterns of physiological arousal that are found when watching humorous film clips will be found under more naturalistic circumstances (i.e., during married couple conversations).

Individual differences in the use of laughter: Sex, age, marital satisfaction

Sex. Previous research has found sex differences in the use of laughter. During group social interactions on college campuses, women laugh more than men and men elicit more laughs from others than women (Provine, 1993). When watching humorous film clips, women use proportionately more voiced laughs than men (Bachorowski, Smoski, & Owen, 2001). In the context of dyadic interpersonal communications between friends and strangers, women use proportionately more antiphonal laughter than men (Smoski and Bachorowski 2003). Sex differences in the use of laughter in adulthood are believed to persist from early childhood. For men, eliciting laughter in others is believed to indicate social and romantic interest, fitness, and dominance; laughter for women is also believed to indicate social or romantic interest, as well as openness and receptivity (Provine, 1993). Although laughter and smiling are believed to have evolved from different phylogenetic roots, previous research has found similar sex differences in smiling as in laughter. Specifically, women smile more than men under a wide range of social circumstances (LaFrance and Hecht, 2000; Hall, Carney, et al. 2002; Ellis, 2006). Whether these sex differences in the use of laughter are also found during marital interactions has not been studied previously and is a focus of the present study.

Age. Previous research has not investigated age differences in the use of laughter. Previous research does suggest, however, that older adults are more emotionally positive and choose to engage with positive emotional information more than middle-aged adults. Specifically, previous marital research has found that older couples reported experiencing proportionately more positive emotions than middle-aged couples during marital discussions of conflict (Levenson, Carstensen, et al. 1994). Also, previous memory and attention research has found that older adults perform better at recognition memory tasks involving emotionally positive information than either neutral or negative information; a bias not found in younger adults (Murphy & Isaacowitz, 2008). In keeping with these findings, research inspired by Socio-Emotional Selectivity Theory (SEST/Carstensen, 1992) posits that as adults become increasingly aware of nearing the end of life, whether due to aging or illness, they tend to place a premium on emotion related goals (e.g. seeking positive emotional experiences and maintaining satisfying interpersonal relations). As social networks shrink, marriage increasingly constitutes a larger portion of the social world of older adults. Laughter is a behavioral display often associated with positive emotions, such as joy and exhilaration (Ruch, 1993). Therefore, we might expect older couples to laugh more and to display proportionately more laughs associated with positive emotions (Antiphonal, Duchenne, and Voiced) than middle-aged couples.

Marital Satisfaction. Laughter is believed to play important roles in facilitating interpersonal communication as well as social and romantic attachments. Theoretically, laughter may play an especially important role in the context of marriage, a context in which communication quality and the facilitation and maintenance of romantic attachments are especially important. Previous research, however, has not investigated laughter in marriage. That being said, we do know from previous research that satisfied married couples report more positive emotion and less negative emotion during discussions of marital conflict than unsatisfied couples (Levenson, Carstensen, et al. 1994). Because laughter is often associated with positive emotions (Ruch, 1993), we might expect satisfied couples to laugh more than unsatisfied couples.

The present study

As discussed above, we know from previous research that laughter, in response to watching humorous film clips, is typically associated with increased positive emotion (as measured by self-report), increased cardiovascular and electrodermal arousal (including heart rate, respiration rate, and skin conductance), and decreased arterial stiffness (indicated by longer pulse transmission times). We do not know, however, much about the time course of these changes, how these changes persist following laughs, and whether these changes will also be found in more naturalistic and more emotionally varied settings (i.e., middle-age and older couple conversations about marital conflict). It is also unclear whether previous research findings associating laughter with emotional and physiological changes in arousal are dependent on the kinds of laughs involved and whether they also occur in the spouses of individuals who laugh. Previous research has tended to pool all laughs into a single category; however, recent research has demonstrated compelling evidence that laughter is a highly complex and diverse

phenomenon. In the present study, the impact of three different kinds of laughs (Antiphonal, Duchenne, and Voiced) on self-reported emotional experience and physiological arousal was explored in the context of middle-aged and older married couple discussions of conflict. Finally, because people use laughter differently from one another, individual differences in the use of laughter based on sex, age, and marital satisfaction were also explored.

Methods

Participants

The participants were 156 married couples--82 middle-aged couples (mean age 45 years, married for at least 15 years) and 74 older couples (mean age 64 years, married for at least 35 years) living in the East Bay. All (but one couple) were in their first marriage. Participants were recruited in 1989 for a longitudinal study of long-term marriages. The recruitment process utilized a three-stage sampling procedure: First, characteristics of the target population, such as marital satisfaction, ethnicity, and socioeconomic status, and religion were established using a telephone survey. Second, goals for recruitment were established based upon matching the characteristics of the target population defined by the telephone survey. Third, newspaper advertisements, billboards, and placards on the sides of local municipal buses were used to recruit subjects. The sample was constituted so that it generally met the characteristics determined in the telephone survey. Recruitment goals were successfully met regarding marital satisfaction, socioeconomic status, and religion; however, ethnic minority couples that were older and dissatisfied proved to be difficult to recruit. As a result, the final sample over-sampled White couples by 17%. Levenson and colleagues (Levenson, Carstensen, et al. 1993) provide a more detailed discussion of sample recruitment.

The final sample was primarily Caucasian, upper middle class, white collar, well educated, and Judeo-Christian. Specifically, the sample has the following characteristics: (1) Ethnicity: 85.9% White, 5.8% African American, 2.6% Hispanic, 2.6% Asian, and 2.2% in which spouses were of another ethnicity; (2) Household income: The median income category was \$50,000 to \$59,999 with a range of below \$10,000 to above \$100,000; (3) Job status of the primary wage earner: 68.6% white collar, 19.9% pink collar, and 11.5% blue collar; (4) Education: Mean number of years of education was 16.0 with a range of 8 to 20 years; and (5) Religion: 39.7% Protestant, 14.1% Catholic, 13.5% Jewish, 8.3% other religious affiliations, 12.2% no religion, and 12.2% spouses with different religious affiliations.

Procedure

Couples who met study criteria were mailed a questionnaire packet and were scheduled for two three-hour experimental sessions at the Berkeley Psychophysiology Laboratory in the Psychology Department of the University of California at Berkeley. The questionnaire packet (which was filled out and returned prior to the first laboratory visit) included measures of marital satisfaction (see data reduction section for more detailed information). Couples were paid \$150 for their participation. During the first

laboratory visit, couples were seated facing each other and physiological monitoring equipment was attached that continuously monitored autonomic and somatic physiological reactivity. Behavior was continuously recorded on videotape. Couples engaged in three 15-minute conversations--one conversation in each of the following domains (and in the following order): events of the day, marital conflict, and pleasant topic. Each conversation was preceded by a five-minute baseline period, during which couples were asked to sit quietly with their eyes open and to avoid interacting with one another. Prior to the second and third conversation baseline period, a middle-aged female lab assistant met with participants to help them generate ideas and decide upon an appropriate conversation topic. Only data from the second conversation (marital conflict) were used in the present study. Previous research has found this conversation to be richly imbued with emotion and most strongly related to marital satisfaction (Levenson, Carstensen, et al. 1993).

The second visit involved couples watching a videotape record of their marital discussion from their previous laboratory visit and making ratings regarding how they were feeling during the original discussion. Specifically, spouses used a rating-dial to rate their emotional state during the interaction. The dial rotated 180 degrees and has a 9-point scale (1="Extremely Positive", 5="Neutral", 9="Extremely Negative"). Spouses were instructed to adjust the dial as needed so that it always indicated how they were feeling during the original conversation. For this rating task, spouses were seated in the same chairs as the previous visit; however, this time the chairs were turned toward a 25-inch television screen. A temporary partition was erected between the couple so that both spouses could see the television, but not one another.

For the present study, I made use of data from the discussion of marital conflict.

Apparatus

Audio/Visual recording: Two remote-controlled high-resolution cameras, partially concealed by darkened glass, were used to videotape the upper torso and face of each spouse throughout each conversation. Using a video special effects generator, the images of the two spouses were combined onto a single split screen and recorded on a VHS videocassette recorder. Microphones attached to the shirt collar of each spouse were used to record sound. Video and physiological data were synchronized in two ways: (a) a time generating device superimposed the elapsed time on the video recording—this timer was started by the computer system at the start of each conversation; and (b) a brief tone was recorded on one of the audio channels of the videotape at the beginning of each conversation (this tone could be detected by the computer to synchronize data collection when the couple watched and rated the first session recordings during their second visit).

Physiological recording: A Grass Model 7 12-channel polygraph and a microcomputer with digital and analog input and output capabilities were used to monitor seven physiological measures continuously, averaging them every second during the conversations. The measures were: (1) Inter-beat interval: Beckman miniature electrodes with Redux paste were placed in a bipolar configuration on opposite sides of the subject's chest. The inter-beat interval was calculated as the interval (in milliseconds) between successive R waves of the heart. (2) Skin conductance level: A constant-

voltage device was used to pass a small electric current between Beckman regular electrodes (using an electrolyte of sodium chloride in unibase) attached to the palmar surface of the middle phalanges of the first and third fingers of the non-dominant hand. (3) Finger temperature: A thermistor attached to the palmar surface of the distal phalange of the fourth finger, recorded temperature in degrees Fahrenheit. (4) Finger pulse amplitude: A UFI photoplethysmograph recorded the amplitude of blood volume in the finger using a photocell taped to the distal phalange of the second finger of the non-dominant hand. (5) Finger pulse transmission time: The time interval in milliseconds was measured between the R wave of the electrocardiogram (EKG) and the upstroke of the peripheral pulse at the finger site. (6) Ear pulse transmission time: A UFI photoplethysmograph attached to the right earlobe recorded the volume of blood in the ear. The time interval in milliseconds was measured between the R wave of the EKG and the upstroke of peripheral pulse at the ear site. (7) General somatic activity: An electromechanical transducer attached to the platform under the participant's chair generated an electrical signal proportional to the amount of movement in any direction. These seven physiological signals were chosen to sample broadly from major organ systems related to emotional arousal; namely, cardiovascular, thermoregulatory, electrodermal, and muscular (somatic).

Coding of laughs

Videotaped recordings obtained in 1989-90 of the discussions of an ongoing marital conflict were used. For the present study, I identified each laugh for each spouse in the video recording and then coded it into three categories as follows:

Identification and timing of a laugh occurrence. A laugh was defined as a sharp exhale or a series of sharp exhales that did not resemble a cough, sigh, or a clearing of the throat. Laugh onsets were indicated by a sharp increase in Somatic Activity (see above); and laugh offsets were indicated by Somatic Activity returning to near pre-laugh levels. Laugh Onset Times and Offset Times were identified for each laugh by matching laugh onsets and offsets with the timing information (see above under heading "Audio/Visual recording") on the video recording.

Laugh codes. Each laugh was rated in terms of three dichotomous codes (i.e., yes, no). An individual laugh could receive a yes rating for more than one code. The codes were as follows:

1. Antiphonal laughter: Antiphonal laughter is laughter (as defined above) that occurs during another's laughter or in direct response to another's laughter (Smoski & Bachorowski, 2003).

2. Duchenne laughter: Duchenne laughter is defined as laughter that is accompanied by contraction of the orbicularis oculi muscles surrounding the eyes, indicated by pouching of the lower eyelids, crows-feet in the outer corners of the eyes, and increased light reflecting off of the eyes due to increased hydrostatic pressure within the eyes.

3. Voiced laughter: Voiced laughter is laughter that engages the vocal-chords and has a singsong like quality (Bachorowski & Owren, 2001). Silent laughs and audible laughs that did not engage the vocal chords, such as breathy laughs and laughs that sounded more like grunts or whistles were coded as non-Voiced.

Additional summary variables. Summary variables were created based on the laughter codes described above.

4. Total Frequency of Laughs: A simple count of the number of laughs of all kinds that a spouse displayed over the course of the conflict conversation.

5. Proportion of each Kind of Laugh: This was computed by dividing the number of occurrences of a particular laughter code by the Total Frequency of Laughs.

Behavior coding training. Ten behavior coders were trained in a coding system that included two behavior codes: Antiphonal and Voiced. Once initial agreement between coders was established, a coder was assigned to code all of the laughter moments of a couple's conflict conversation. Twenty percent of each coder's ratings overlapped with another coder's ratings to establish reliability. The overall mean Cohen's Kappa for all laughter coders was .82, indicating very high agreement between coders (Cohen, 1960). When the coding of overlapping coders was in disagreement, those laughs were presented to the coding team at weekly meetings and discussed until consensus was reached. One coder trained in the Facial Action Coding System (Ekman & Friesen, 1975) made distinctions between Duchenne and non-Duchenne laughs. FACS is an anatomically based facial behavior coding system designed to detect facial movements associated with emotion.

Data reduction: Marital Satisfaction, emotional experience, and physiology

Marital Satisfaction. Marital satisfaction was measured using two well-validated questionnaires--the Locke Wallace Marital-Adjustment Test and the Marital Relationship Inventory (Locke & Wallace, 1959; Brodman, 1974). Both questionnaires ask questions such as "If you were to live your life over again, would you marry the same spouse?" The scores on the Locke Wallace Marital-Adjustment Test (a 15-item questionnaire) and the Marital Relationship Inventory (a 22-item questionnaire) were averaged to create a single marital satisfaction composite score.

Emotional experience. To compare self-reported emotional experience occurring before, during, and after laughs, three "Laugh Timing" epochs were created for averaging second by second rating dial data. The first epoch, called *Pre-Laugh*, captured rating dial data corresponding to the 10 seconds preceding laughs. Therefore, it included the 10 seconds prior to the Start Time (i.e., when somatic activity sharply increased) of laughs. The second epoch, called *Laugh*, captured self-reported emotion corresponding to the onset and offset of laughs. Therefore, the *Laugh* epoch began at the Start Time for each laugh and ended at the Stop Time (i.e., when somatic activity returned to near Pre-Laugh levels) for each laugh. The third epoch, called *Post-laugh*, captured self-reported emotion data corresponding to the 10 seconds following laughs. Therefore, it began at

the Stop time for each laugh and ended 10 seconds after the Stop time for each laugh. For each laugh, the second-by-second self-reported emotion data was averaged within each Laugh Timing epoch. For spouses who had multiple laughs of the same kind, the second-by-second averages for each Laugh Timing epoch were averaged across laughs. Therefore, each spouse contributed at most one data value for each kind of laugh to the data analyses.

Physiological arousal. For each physiological measure, second-by-second data was normalized (i.e., convert to z-scores based on the overall mean and standard deviation during the 15 minute conflict conversation for that measure) for each spouse. Normalized values with smaller values associated with higher arousal (e.g., heart rate inter-beat interval, finger-pulse transit time, ear pulse transit time, and finger pulse amplitude) were multiplied by -1 . Normalized physiology data was averaged within spouse, within each Laugh Timing data bin (Pre-Laugh, Laugh, and Post Laugh, see above), and within laughs, and then averaged across laugh types (if a spouse had more than one laugh of that kind).

Aims and Hypotheses

Aim #1: To determine how self-reported emotion and physiological arousal change during laughs

Hypothesis 1a. Self-reported emotional experience will become more positive during laughs compared to before laughs and following laughs compared to before laughs.

Rationale. Laughter is closely intertwined with positive emotions such as amusement, joy, and exhilaration (Ruch, 1995). Amusement has been found to undo emotional experience associated with negative emotions (Fredrickson & Levenson, 1998). Therefore, I predicted that self-reported emotion would become more positive during laughs and these emotional gains would persist following laughs.

Hypothesis 1b. Inter-beat interval, skin conductance, temperature, and somatic activity arousal will be higher during laughs compared to before laughs and lower following laughs compared to before laughs.

Rationale. Previous laughter research investigating exhilaration and joy found laughter to be associated with increased heart rate, respiratory rate, and skin conductance (Ruch, 1995; Marci, Moran, et al. 2004). Therefore, I predicted in the present study that this general pattern of physiological activity would also be found in the present study.

Previous research has found positive emotions, such as amusement, undo physiological arousal associated with negative emotions, restoring physiological equilibrium (Fredrickson & Levenson, 1998). Given the close relationship between laughter and amusement, I predicted in the present study that laughter would undo physiological arousal, leaving spouses with lower arousal in inter-beat interval (i.e., longer intervals), skin conductance (i.e., lower conductance), temperature (i.e., lower temperature), and somatic activity (i.e., lower activity) Post-Laugh than Pre-Laugh.

Hypothesis 1c. Finger pulse amplitude, finger pulse transit time, and ear pulse transit time arousal will be lower during laughs compared to before laughs and lower following laughs compared to before laughs.

Rationale. Previous research has not investigated the relationship between laughter and finger pulse amplitude, finger pulse transit time, and ear pulse transit time. There is evidence, however, that laughter is associated with decreased arterial stiffness, as indicated by carotid-femoral pulse wave velocity (Vlachopoulos, Panagiotis, et al. 2009). Decreased arterial stiffness may be an indication of vasomotor relaxation. Therefore, I predicted that laughter in the present study would be associated with lower arousal in finger pulse amplitude (i.e., larger amplitudes), finger pulse transit time (i.e., longer transit times), and ear pulse transit time (i.e., longer transit times). Previous research has found positive emotions, such as amusement, undo physiological arousal associated with negative emotions, restoring physiological equilibrium (Fredrickson & Levenson, 1998). Given the close relationship between laughter and amusement, I predicted in the present study that laughter would undo physiological arousal, leaving spouses with lower arousal in finger pulse amplitude (i.e., larger amplitudes), finger pulse transit time, and ear pulse transit time arousal levels Post-Laugh than Pre-Laugh.

Aim #2: To determine how different kinds of laughs are associated with changes in self-reported emotion and physiological arousal

Emotional Experience

Hypothesis 2a. Self-reported emotion will be more positive during laughs (Laughs) for Antiphonal than non-Antiphonal laughs.

Rationale. Previous research found that Antiphonal laughter was an indication of social bonding and shared positive regard (Smoski & Bachorowski, 2003). It seems reasonable to expect that interpersonal indications of social bonding and shared positive regard will increase positive emotions. Therefore, I predicted that self-reported emotion would be more positive during laughs (Laughs) for antiphonal than non-Antiphonal laughter.

Hypothesis 2b. Self-reported emotion will be more positive during laughs (Laughs) for Duchenne than non-Duchenne laughs.

Rationale. High amounts of Duchenne laughter (and not overall amounts of laughter) were associated with high positive emotion and low negative emotion in other contexts (Keltner & Bonanno, 1997). Therefore, I predicted that self-reported emotion would be more positive during laughs (Laughs) for Duchenne laughter than non-Duchenne laughter.

Hypothesis 2c. Self-reported emotion will be more positive during laughs (Laugh) for Voiced than non-Voiced laughs.

Rationale. Voiced laughter has been found to elicit more positive emotion in non-laughing partners than non-Voiced laughs (Bachorowski & Owren, 2001). Therefore, I predicted in the present study that self-reported emotion would be more positive during laughs (Laughs) for Voiced than non-Voiced laughter.

Physiological arousal

Hypothesis 2d. Antiphonal laughs will have higher inter-beat interval, skin conductance, temperature, and somatic activity arousal levels during laughs (Laugh) and lower arousal levels following laughs (Post Laugh) than non-Antiphonal laughs.

Antiphonal vs. non-Antiphonal laughs

Rationale. Previous research has not investigated associations between Antiphonal laughter and physiological arousal. Antiphonal laughter, however, is closely related to Shared laughter—Shared laughter is defined as laughter between two or more people that overlaps temporally. Shared laughter has been found to be more strongly associated with increased Skin Conductance (Marci, Moran, et al. 2004) than non-Shared laughter. Therefore, I predicted in the present study that greater skin conductance arousal would be found for Antiphonal than non-Antiphonal laughs, and I predicted this pattern of greater physiological arousal for Antiphonal than non-Antiphonal laughs would generalize to other measures, including inter-beat interval (i.e., shorter intervals) temperature (i.e., higher temperature), and somatic activity arousal (i.e., more movement). Also, since Antiphonal laughter is believed to be associated with feelings of shared positive regard, and positive emotions have been found to undo pre-existing physiological arousal (Fredrickson & Levenson, 1998), I predicted that Antiphonal laughter would have lower inter-beat, skin conductance, temperature, and somatic activity arousal levels following laughs than non-Antiphonal laughs.

Hypothesis 2e. Duchenne laughs will have higher inter-beat interval, skin conductance, temperature, and somatic activity arousal levels during laughs (Laugh) and lower arousal levels following laughs (Post Laugh) than non-Duchenne laughs.

Duchenne vs. non-Duchenne laughs

Rationale. Previous research found Duchenne laughter to be more strongly associated with genuinely felt positive emotion than non-Duchenne laughter (Keltner & Bonanno, 1997). Changes in emotional experience tend to correlate with changes in physiological arousal (Levenson, 2003). Therefore, I predicted that Duchenne laughter would be associated with greater increases in inter-beat interval, skin conductance, temperature, and somatic activity arousal levels than non-Duchenne laughter. Also, since Duchenne laughter is strongly associated with positive emotions, and positive emotions have been found to undo pre-existing physiological arousal (Fredrickson & Levenson, 1998), I predicted that Duchenne laughter would have lower inter-beat, skin conductance, temperature, and somatic activity arousal levels following laughs than non-Duchenne laughs.

Hypothesis 2f. Voiced laughs will have higher inter-beat interval, skin conductance, temperature, and somatic activity arousal levels during laughs (Laugh) and lower arousal levels following laughs (Post Laugh) than non-Voiced laughs.

Voiced vs. non-Voiced laughs

Rationale. Previous research found Voiced laughter to evoke more positive emotion in others than non-Voiced laughs (Bachorowski & Owren, 2001). Changes in emotional experience tend to correlate with changes in physiological arousal (Levenson, 1993). Therefore, I predicted that Voiced laughter would have higher inter-beat interval, skin conductance, temperature, and somatic activity arousal levels during laughs (Laughs). Also, since Voiced laughter is strongly associated with positive emotions, and positive emotions have been found to undo pre-existing physiological arousal (Fredrickson and Levenson, 1998), I predicted that Voiced laughter would have lower inter-beat interval, skin conductance, temperature, and somatic activity arousal levels following laughs than non-Voiced laughs.

Hypothesis 2g. Antiphonal laughs will have lower finger pulse amplitude, finger pulse transit time, and ear pulse transit time arousal during laughs (Laugh) and following laughs (Post Laugh) compared to non-Antiphonal laughs.

Rationale. See Rationale for Hypothesis 2i.

Hypothesis 2h. Duchenne laughs will have lower finger pulse amplitude, finger pulse transit time, and ear pulse transit time arousal during laughs (Laugh) and following laughs (Post Laugh) compared to non-Duchenne laughs.

Rationale. See Rationale for Hypothesis 2i.

Hypothesis 2i. Voiced laughs will have lower finger pulse amplitude, finger pulse transit time, and ear pulse transit time arousal during laughs (Laugh) and following laughs (Post Laugh) compared to non-Voiced laughs.

Rationale. Previous research has found laughter to be associated with both physiological arousal increases--heart rate, respiration rate, and skin conductance (Ruch, 1995; Marci, Moran, et al. 2004)--and decreases--pulse wave velocity (Vlachopoulos, Panagiotis, et al. 2009). It is unknown, however, how these two systems of physiological arousal (those that increase and those that decrease during laughter) change relative to one another. I predicted that the greater increases in positive emotion and physiological arousal that I predicted (in Hypotheses 2a to 2f) for Antiphonal, Duchenne, and Voiced laughs, compared to non-Antiphonal, non-Duchenne, and non-Voiced laughs, would be accompanied by greater decreases in finger pulse amplitude, finger pulse transit time, and ear pulse transit time arousal.

Aim #3: To determine individual differences in the use of laughter based on sex, age, and marital satisfaction

Sex differences

Hypothesis 3a. Wives will laugh more than husbands.

Rationale. See Rationale for Hypothesis 3b.

Hypothesis 3b. Wives will use proportionately more Antiphonal laughs than husbands.

Rationale. Previous research investigating laughter in group-settings on college campuses found that women tend to laugh more than men (Provine, 1993). Previous research investigating dyadic interactions between friends and strangers found that women tend to use proportionately more Antiphonal laughter than men (Marci, Moran, et al., 2004). Therefore, I predicted in the present study that these sex differences found in other contexts would also be found in the context of marital discussions of conflict.

Age differences

Hypothesis 3c. Older adults will use proportionately more Antiphonal, Duchenne, and Voiced Laughs than middle-aged adults.

Rationale. Research inspired by Socio-emotional Selectivity Theory (SEST/Carstensen, 1992) found that as adults become increasingly aware of nearing the end of life, whether due to aging or illness, they tend to place a premium on emotion related goals (e.g. seeking positive emotional experiences and maintaining satisfying interpersonal relations). As social networks shrink, marriage increasingly constitutes a larger portion of the social world of older adults. Three kinds of laughs are thought to be associated with positive emotion and the facilitation of interpersonal relationships. Antiphonal laughter is believed to communicate shared positive regard and openness to interpersonal communication (Smoski & Bachorowski, 2003), which may increase positive emotion. Duchenne laughter has been found to be more strongly associated with genuinely felt positive emotions than non-Duchenne laughter (Keltner & Bonanno, 1997). Audio recordings of Voiced Laughter has been shown to instill greater positive emotions in others than non-Voiced laughter (Bachorowski, Smoski, et al. 2001). Therefore, Antiphonal, Duchenne, and Voiced laughs are all related to positive social and emotional experiences. Based on these findings, I predicted that older couples would use relatively more Antiphonal, Duchenne, and Voiced laughs than middle-aged couples.

Marital satisfaction differences

Hypothesis 3d. Satisfied couples will laugh more than unsatisfied couples.

Rationale. The quality of interpersonal communication is an important component of marital satisfaction (Gottman & Levenson, 2000). Previous research has

found that laughter facilitates interpersonal communication (Provine, 1993). Therefore, I predicted that greater marital satisfaction would be associated with greater amounts of laughter.

Hypothesis 3e. Satisfied couples will use proportionately more Antiphonal, Duchenne, and Voiced Laughs than unsatisfied couples.

Rationale. In addition to interpersonal communication quality, positive emotion is another important component of marital satisfaction (Gottman & Levenson, 2000). Antiphonal, Duchenne, and Voiced laughs are believed to increase positive emotion. Specifically, Antiphonal laughter is believed to communicate shared positive regard and openness to interpersonal communication (Smoski & Bachorowski, 2003), which may increase positive emotion. Duchenne laughter has been found to be more strongly associated with genuinely felt positive emotions than non-Duchenne laughter (Keltner & Bonanno, 1997). Audio recordings of Voiced Laughter has been shown to instill greater positive emotions in others than non-Voiced laughter (Bachorowski, Smoski, et al. 2001). Therefore, I predicted that greater marital satisfaction would be associated with a larger proportion of positive laughs (Antiphonal, Duchenne, and Voiced laughs) than unsatisfying marriages.

Data Analyses

Aim #1: To determine how self-reported emotion and physiological arousal change during laughs

To investigate the relationship between laughter and changes in emotional experience and physiological arousal, 2 X 3 Repeated Measures Multivariate Analysis of Variance (MANOVA) were conducted with Spouse (husbands and wives) and Laugh Timing (Pre-Laugh, Laugh, and Post-Laugh) as within subject factors for the following dependent variables: Self-Reported Emotion, Inter-beat Interval, Skin Conductance, Temperature, Somatic Activity, Finger Pulse Amplitude, Finger Pulse Transit Time, and Ear Pulse Transit Time. Spouse was entered as a repeated measure factor to accommodate the nested nature of the data (i.e., laughter between husbands and wives tends to be highly correlated) and to test whether husband patterns of emotional experience and physiological arousal associated with laughs were different than wives. Laugh Timing was entered as a repeated measure factor to test whether patterns of emotional experience and physiological arousal changed over the course of laughs, including before, during, and after.

Significant interactions were investigated further using post hoc within-subjects t-tests with a Bonferroni ($p < .05$) correction for multiple tests.

Aim #2: To determine the impact of different kinds of laughs on emotional experience and physiological arousal

To investigate differences between kinds of laughs (Antiphonal vs. non-Antiphonal; Duchenne vs. non-Duchenne; and Voiced vs. non-Voiced) regarding changes

in emotional experience and physiological arousal, 2 X 2 X 3 Repeated Measures Multivariate Analysis of Variance (MANOVA) with Spouse (husbands and wives), Laugh Kind (each laugh was coded “yes” or “no” for each kind of laugh), and Laugh Timing (Pre-Laugh, Laugh, and Post-Laugh) as within subject variables were conducted for each comparison between kinds of laugh and for each of the following dependent variables: Self-Reported Emotion, Inter-beat Interval, Skin Conductance, Temperature, Somatic Activity, Finger Pulse Amplitude, Finger Pulse Transit Time, and Ear Pulse Transit Time. Spouse was entered as a repeated measure variable to accommodate the nested nature of the data. Significant interactions were investigated further, using post hoc within-subjects t-tests with a Bonferroni ($p < .05$) correction for multiple tests.

Aim #3: To determine individual differences in the use of laughter based on spouse, age, and marital satisfaction

To investigate individual differences in the use of laughter, a 2 X 2 X 2 Univariate ANOVA with Spouse (husband and wife), Age (middle-aged and older adults), and Marital Satisfaction (satisfied and dissatisfied) as between subject variables was conducted for each of the following dependent variables: Total Frequency of Laughs, Proportion of Antiphonal Laughs, Proportion of Duchenne Laughs, and Proportion of Voiced Laughs. Significant interactions between independent variables were investigated further using post hoc within-subject t-tests with a Bonferroni ($p < .05$) correction for multiple tests.

Results

Frequency of laughs

One hundred and fifty-six couples were recruited in the original study. Twenty-nine couples who participated in the original study were excluded from the present study either because of problems with the physiological data (12 couples), missing videotapes (4 couples), or because the couples did not laugh (13 couples). Across all of the remaining 127 couples, there were a total of 2,214 laughs (husband laugh frequency = 986; wife laugh frequency = 1,228). On average, couples laughed 17.0 times (husband mean = 7.6; wife mean = 9.4) per conflict conversation with a range of 0 to 78 laughs (husband range = 0 to 37; wife range = 0 to 42). The modal number of laughs per couple was six (husband mode = 3; wife mode = 5); and the amount of laughter during couple interactions was highly correlated between husbands and wives, $r(119) = .99, p < .000$.

Duration of laughs

Laugh duration was measured using Somatic Activity, which tends to be the first and last observable sign that a laugh has occurred. Within the temporal envelope defined by the start and end of Somatic Activity, staccato breathing (brief and sharp exhalations of air occurring in quick succession) typically begins one second after somatic activity has begun. The length of time associated with staccato breathings is variable depending on the duration of laughs; however, it tends to end five seconds before Somatic Activity ends.

On average, laugh duration was 7.5 seconds (husband mean = 7.4 sec; wife mean = 7.7 sec) with a range between 0 and 187 seconds (husband range = 0 to 186 sec; wife range = 0 to 187 sec). The modal laugh duration for both husbands and wives was 6 seconds, making up nearly half all laughs (1,042). As laugh duration increased, the frequency of laughs decreased asymptotically (see Figure 1). Ninety eight point six percent of all laughs were fifteen seconds or less in duration.

Qualitative description of self-reported emotional experience associated with laughter

For qualitative purposes, self-reported emotion ratings (recall that these were obtained when spouses rated their emotions using a rating dial while viewing video recordings of their actual marital interactions) were averaged second by second and graphed for laughs of varying durations (see Figures 2). A common pattern emerged. The emotion ratings became more positive at the start of laughs, increased in positively steadily and moderately during laughs, and remain elevated throughout the 10-second period following laughs. As the duration of laughs increased, the positivity of self-reported emotion also tended to increase (i.e., longer laughs were rated more positively).

Qualitative description of physiological arousal patterns associated with laughter

For qualitative purposes, average second by second graphs were made for each of the seven channels of physiological arousal for laughs lasting seven seconds (see Figure 3). Seven-second laughs were chosen because of the relatively large number of them (25% of the total number of laughs) and because they demonstrate well the pattern of physiological arousal found across laughs of different durations. These plots were used to describe similarities and differences between physiological measures regarding timing of onset and offset, direction of response (increase or decrease), and responsiveness associated with laughter.

Laughs typically began with a sharp increase in Somatic Activity. One second later, staccato breathing typically began, as well as sharp increases (0.1 standard deviations per second) in Inter-beat Interval arousal (i.e., Inter-beat Intervals shortened) and sharp decreases (-0.075 standard deviations per second) in Ear Pulse Transit Time arousal (i.e., Ear Pulse Transit Time lengthened, indicating decreased arousal). Two seconds after the start of laughs, Finger Pulse Transit Time arousal tended to decrease (lengthen) sharply (-0.075 standard deviations per second); and three seconds after the start of laughs, Skin Conductance tended to increase slightly (0.01 standard deviations per second). Temperature and Finger Pulse Amplitude were unresponsive to laughter. All measures that responded to laughter (with the exception of Skin Conductance) tended to return to near Pre-Laugh levels between five and seven seconds after staccato breathing ended. Skin Conductance, however, tended to remain slightly elevated for fifteen seconds after staccato breathing ended.

As laughs increased in duration, the basic pattern of physiological arousal remained unchanged. What did change, however, was longer laughs tended to have larger physiological responses (including both arousal increases and arousal decreases) than shorter laughs. Specifically, longer laughs had greater Somatic Activity, Inter-beat Interval (i.e., shorter intervals), and Skin Conductance arousal than shorter laughs (for an

example, see Figure 4); and longer laughs had lower Finger Pulse Transit Time (i.e., slower transit times) and Ear Pulse Transit Time (i.e., slower transit times) arousal than shorter laughs (for an example, see Figure 5).

Aim #1: To determine how self-reported emotion and physiological arousal change during laughs

Hypothesis 1a. Self-reported emotional experience will become more positive during laughs compared to before laughs and following laughs compared to before laughs.

A main effect was found for Laugh Timing, $F(2, 100) = 37.52, p < .001, \eta^2 = .20$. As predicted, self-reported emotion became more positive from Pre-Laugh to Laugh (Mean: Pre-Laugh = 5.00, Laugh = 5.25; $t[50] = -8.11, p < .000$) and from Pre-Laugh to Post Laugh (Mean: Pre-Laugh = 5.00, Post Laugh = 5.25; $t[50] = -6.78, p < .000$). Self-reported emotion also became more positive from Laugh to Post Laugh (Mean: Laugh = 5.18, Post Laugh = 5.25; $t[50] = -2.78, p < .006$).

Therefore, the hypothesis that laughter would be associated with self-reported emotion becoming more positive during (Pre-Laugh vs. Laugh) and following (Pre-Laugh vs. Post Laugh) laughs was supported.

Hypothesis 1b. Inter-beat interval, skin conductance, temperature, and somatic activity arousal levels will be higher during laughs compared to before laughs and lower following laughs compared to before laughs.

Inter-beat Interval

A main effect was found for Laugh Timing, $F(2, 208) = 78.98, p < .001, \eta^2 = .43$. As predicted, Inter-beat Interval arousal levels increased (i.e., shortened) from Pre-Laugh to Laugh (Means: Pre-Laugh = .02, Laugh = .17; $t[104] = -12.90, p < .000$), but did not decrease (i.e., lengthen) Pre-laugh to Post-Laugh (Means: Pre-Laugh = .02, Post-Laugh = .04; $t[104] = -1.74; p = \text{NS}$). Inter-beat Interval arousal levels did, however, decrease from Laugh to Post-Laugh (Means: Laugh = .17, Post-Laugh = .04; $t[104] = 9.22, p < .000$).

Skin Conductance

A main effect was found for Laugh Timing, $F(2, 208) = 37.29, p < .001, \eta^2 = .27$. As predicted, Skin Conductance increased from Pre-Laugh to Laugh (Means: Pre-Laugh = -.009, Laugh = -.0004; $t[104] = -9.79, p < .000$). Contrary to prediction, however, Skin Conductance also increased Pre-Laugh to Post-Laugh (Means: Pre-Laugh = -.009, Post-Laugh = -.004; $t[104] = -7.91, p < .001$) and Laugh to Post-Laugh (Means: Laugh = .0004, Post-Laugh = .004; $t[104] = -3.00, p < .005$).

Temperature

Contrary to prediction, no main effect was found for Laugh Timing, $F(2, 208) = 2.10, p > .05$.

Somatic Activity

A main effect was found for Laugh Timing, $F(2, 208) = 73.97, p < .001, \eta^2 = .42$. As predicted, Somatic Activity increased from Pre-Laugh to Laugh (Means: Pre-Laugh = .06, Laugh = .18; $t[104] = -10.00, p < .000$); but failed to decrease Pre-Laugh to Post-Laugh (Means: Pre-Laugh = .06, Post-Laugh = .07; $t[104] = -1.33, p = \text{NS}$). Somatic Activity did, however, decrease from Laugh to Post-Laugh (Means: Laugh = .18, Post-Laugh = .07, $t[104] = 8.79, p < .000$).

Summary of findings for Hypothesis 1b

The hypothesis that Inter-beat Interval, Skin Conductance, Temperature, and Somatic Activity arousal will increase during laughs (Pre-Laugh to Laugh) and decrease following laughs (Pre-Laugh to Post Laugh) was partially supported in three of four physiology measures: Inter-beat Interval, Skin Conductance, and Somatic Activity arousal increased during Laughs; however, they failed to decrease Post Laugh to arousal levels lower than Pre-Laugh. No changes in Temperature were found during Laughs or Post-Laughs.

Hypothesis 1c. Finger pulse amplitude, finger pulse transit time, and ear pulse transit time arousal will be lower during laughs (Laugh) and lower following laughs (Post Laugh) than before laughs (Pre-Laugh).

Finger Pulse Amplitude

Contrary to prediction, no main effect was found for Laugh Timing, $F(2, 208) = 2.84, p > .05$.

Finger Pulse Transit Time

A main effect was found for Laugh Timing, $F(2, 208) = 7.60, p < .001, \eta^2 = .07$. As predicted, Finger Pulse Transit Time arousal decreased (i.e., slowed) from Pre-Laugh to Laugh (Means: Pre-Laugh = .12, Laugh = .06; $t[104] = 4.80, p < .000$) and decreased from Pre-Laugh to Post-Laugh (Means: Pre-Laugh = .12, Post-Laugh = .06; $t[104] = 4.38, p < .000$).

Ear Pulse Transit Time

A main effect was found for Laugh Timing, $F(2, 208) = 14.91, p < .001, \eta^2 = .13$. As predicted, Ear Pulse Transit Time arousal decreased (i.e., slowed) from Pre-Laugh to Laugh (Means: Pre-Laugh = .05, Laugh = .02; $t[104] = 3.03, p < .005$); however, no differences were found between Pre-Laugh and Post-Laugh (Means: Pre-Laugh = .05, Post-Laugh = .07; $t[104] = -3.29, p = \text{NS}$). Ear Pulse Transit Time arousal

increased (i.e., sped up) from Laugh to Post-Laugh (Means: Laugh = .02, Post-Laugh = .07; $t[104] = -5.09, p < .000$).

Summary of findings for Hypothesis 1c

The hypothesis that laughter will be associated with decreases in normalized arousal values for Finger Pulse Amplitude, Finger Pulse Transit Time, and Ear Pulse Transit Time during (Pre-Laugh to Laugh) and following (Pre-Laugh to Post Laugh) laughs was supported for Finger Pulse Transit Time, partially supported for Ear Pulse Transit Time, and was not supported for Finger Pulse Amplitude. As predicted, Finger Pulse Transit Time decreased (i.e., slowed) during Laughs and decreased during Post Laughs. Also as predicted, Ear Pulse Transit Time decreased (i.e., slowed) during Laughs; however, failed to decrease Post-Laugh. No changes in Finger Pulse Amplitude were found during Laughs or Post-Laughs.

Aim #1: Summary of findings

Laughter was associated with self-reported emotion becoming more positive during and following laughs. Laughter was associated with physiological arousal increases (Inter-beat Interval, Skin Conductance, and Somatic Activity) and decreases (Finger Pulse Transit Time and Ear Pulse Transit Time) during laughs. These findings suggest that laughter engages two systems of physiological arousal, one that increases in arousal and one that decreases in arousal during laughter. Nearly no support (one out of seven physiology channels) was found for physiological arousal decreases following laughs.

Aim #2: To determine how different kinds of laughs are associated with changes in self-reported emotion and physiological arousal

In the present study, 2214 laughs were observed. Of those laughs, roughly half met criteria for Antiphonal (1004), seventy-five percent met criteria for Voiced (1689), and eighty percent met criteria for Duchenne (1882). A large proportion of laughs met criteria for multiple kinds of laughs (see Table 1).

Emotional experience

Hypothesis 2a. Self-reported emotion will be more positive during laughs (Laugh) and following laughs (Post Laugh) for Antiphonal compared to non-Antiphonal laughs.

No main effect was found for Laugh Kind $F(1, 59) = 1.07, p > .05$; however, a Laugh Kind X Laugh Timing interaction was found, $F(2, 118) = 8.053, p < .005, \eta^2 = .13$. As predicted, when comparing Antiphonal to non-Antiphonal laughter, self-reported emotion was more positive during Laughs (Means: Antiphonal = 5.30, non-Antiphonal = 5.12; $t[59] = -2.70, p < .01$) and during Post Laughs (Means: Antiphonal = 5.39, non-Antiphonal Laughs = 5.16; $t[59] = -3.81, p < .001$) for Antiphonal laughter.

Therefore, the hypothesis that self-reported emotion will be more positive during laughs and following laughs for Antiphonal laughs compared to non-Antiphonal laughs was fully supported.

Hypothesis 2b. Self-reported emotion will be more positive during laughs (Laugh) and following laughs (Post Laugh) for Duchenne compared to non-Duchenne laughs.

A main effect was found for Laugh Kind, $F(1, 36) = 7.121, p < .05, \eta^2 = .20$; self-reported emotion ratings were more positive for Duchenne than non-Duchenne laughs (Means: Duchenne = 5.21, non-Duchenne = 4.88). As predicted, these differences were found during Laughs (Means: Duchenne = 5.25, non-Duchenne = 5.00; $t[36] = -3.084, p < .005$) and Post-Laughs (Means: Duchenne = 5.32, non-Duchenne = 5.08; $t[36] = -2.77, p < .01$).

Therefore, the hypothesis that self-reported emotion will be more positive during laughs and following laughs for Duchenne compared to non-Duchenne laughs was fully supported.

Hypothesis 2c. Self-reported emotion will be more positive during laughs (Laugh) and following laughs (Post Laugh) for Voiced compared to non-Voiced laughs.

A main effect was found for Laugh Kind, $F(1, 39) = 17.07, p < .005, \eta^2 = .20$; self-reported emotion ratings were more positive for Voiced than non-Voiced laughs (Means: Voiced = 5.30, non-Voiced = 5.03). As predicted this pattern was found during Laughs (Means: Voiced = 5.36, non-Voiced = 5.11; $t[39] = -3.66, p < .005$) and during Post Laughs (Means: Voiced = 5.33, non-Voiced = 5.17; $t[39] = -2.177, p < .05$). Self-reported emotion was also more positive for Voiced laughs than non-Voiced laughs during Pre-Laughs (Means: Voiced = 5.16, non-Voiced = 4.94; $t[39] = -3.08, p < .005$).

Therefore, the hypothesis that self-reported emotion will be more positive during laughs and following laughs for Voiced compared to non-Voiced laughs was fully supported.

Summary of findings comparing patterns of self-reported emotion between different kinds of laughs (Hypotheses 2a, 2b, and 2c)

As predicted, self-reported emotion was more positive during and following laughs for Antiphonal, Duchenne, and Voiced laughs compared to non-Antiphonal, non-Duchenne, and non-Voiced laughs, respectively.

Hypothesis 2d. Antiphonal laughs will have higher inter-beat interval, skin conductance, temperature, and somatic activity arousal levels during laughs (Laugh) and lower arousal levels following laughs (Post Laugh) than non-Antiphonal laughs.

Antiphonal vs. non-Antiphonal laughs

Main effects were found for Laugh Kind in three of four physiology measures: Inter-beat Interval, $F(1, 59) = 27.73, p < .001, \eta^2 = .31$; Skin Conductance, $F(1, 59) = 17.28, p < .005, \eta^2 = .22$; and Somatic Activity $F(1, 59) = 43.93, p < .005, \eta^2 = .43$. In

each case, Antiphonal laughter was associated with higher physiological arousal than non-Antiphonal laughter: Inter-beat Interval Means: Antiphonal = .07, non-Antiphonal = .01 (as discussed previously, Inter-beat Interval values were reverse scored so that larger values indicate greater arousal—i.e., shorter Inter-beat Intervals); Skin Conductance Means: Antiphonal = -.02, non-Antiphonal = -.01; and Somatic Activity Means: Antiphonal = .14, non-Antiphonal = .09. No main effect for Laugh Kind was found for Temperature, $F(1, 59) = 3.18, p > .05$.

Laugh Kind X Laugh Timing interactions were found for Inter-beat Interval ($F[2, 118] = 20.71, p < .001, \eta^2 = .25$), Skin Conductance, ($F[2, 118] = 23.53, p < .001, \eta^2 = .27$), and Somatic Activity, ($F[2, 118] = 30.62, p < .001, \eta^2 = .34$); but not for Temperature ($F[2, 118] = .711, p > .05$). As predicted, Antiphonal laughs had higher arousal levels than non-Antiphonal laughs during Laughs: Inter-beat Interval Means: Antiphonal = .22, non-Antiphonal = .08, $t[62] = -8.13, p < .001$; Skin Conductance Means: Antiphonal = -.01, non-Antiphonal = -.02, $t[62] = -3.93, p < .001$; and Somatic Activity Means: Antiphonal = .26, non-Antiphonal = .14, $t[-7.89] = , p < .001$. During Post Laughs, however, Antiphonal laughter failed to have lower arousal levels than non-Antiphonal laughter. To the contrary, Antiphonal laughter had greater Skin Conductance arousal than non-Antiphonal laughter during Post Laughs (Skin Conductance Means: Antiphonal = -.007, non-Antiphonal = -.01, $t[62] = -4.02, p < .001$); and no Post Laugh differences were found for Inter-beat Interval (Means: Antiphonal = .04, non-Antiphonal = .01, $t[62] = -1.17, p = NS$) or Somatic Activity (Means: Antiphonal = .09, non-Antiphonal = .09, $t[62] = -.317, p = NS$).

Therefore, the hypothesis that Antiphonal laughs will have higher inter-beat interval, skin conductance, temperature, and somatic activity arousal levels during laughs (Laugh) and lower arousal levels following laughs (Post Laugh) than non-Antiphonal laughs was partially supported in three of four physiology measures. As predicted, Antiphonal laughter had higher inter-beat interval (i.e., shorter intervals), skin conductance, and somatic activity (but not temperature) arousal during laughs than non-Antiphonal laughs. Following laughs, however, no support was found for Antiphonal laughter having lower physiological arousal than non-Antiphonal laughter.

Hypothesis 2e. Duchenne laughs will have higher inter-beat interval, skin conductance, temperature, and somatic activity arousal levels during laughs (Laugh) and lower arousal levels following laughs (Post Laugh) than non-Duchenne laughs.

Duchenne vs. non-Duchenne laughs

Main effects for Laugh Kind were found in three of the four physiology measures: Inter-beat Interval, $F(1, 26) = 5.73, p < .05, \eta^2 = .16$; Skin Conductance, $F(1, 26) = 6.04, p < .05, \eta^2 = .18$; and Somatic Activity, $F(1, 26) = 14.01, p < .005, \eta^2 = .34$. In each case, Duchenne laughter was associated with greater arousal than non-Duchenne laughter: Inter-beat Interval Means: Duchenne = .22, non-Duchenne = .18 (as discussed previously, Inter-beat Interval values were reverse scored so that larger values indicate greater arousal—i.e., smaller Inter-beat Intervals), Skin Conductance Means: Duchenne = -.023, non-Duchenne = -.032, and Somatic Activity Means: Duchenne = .31, non-

Duchenne = .26. No main effect for Laugh Kind was found for Temperature, $F(1, 26) = .60, p > .05$.

Laugh Kind X Laugh Timing interactions were found for Inter-beat Interval, $F[2, 52] = 11.65, p < .001, \eta^2 = .29$, and Somatic Activity, $F[2, 52] = 6.98, p < .005, \eta^2 = .20$, but not for Temperature, $F[2, 52] = 2.00, p > .05$, or Skin Conductance, $F[2, 52] = 1.44, p > .05$. As predicted, Duchenne laughs had greater Inter-beat Interval and Somatic Activity arousal than non-Duchenne laughs during laughs (Inter-beat Interval Means: Duchenne = .29, non-Duchenne = .18, $t(26) = -4.83, p < .001$; Somatic Activity Means: Duchenne = .34, non-Duchenne = .25, $t(26) = -4.55, p < .001$). Duchenne laughs, however, were not found to have lower Inter-beat Interval or Somatic Activity arousal than non-Duchenne laughs during Post Laughs (Inter-beat Interval Means: Duchenne = .15, non-Duchenne = .14, $t[28] = -.099, p = NS$; Somatic Activity Means: Duchenne = .24, non-Duchenne = .25, $t[28] = .36, p = NS$).

Therefore, the hypothesis that Duchenne laughs will have higher inter-beat interval, skin conductance, temperature, and somatic activity arousal levels during laughs (Laugh) and lower arousal levels following laughs (Post Laugh) than non-Duchenne laughs was partially supported in two of four physiology measures. As predicted, Duchenne laughter had higher inter-beat interval and somatic activity (but not skin conductance or temperature) arousal during laughs than non-Duchenne laughs. Following laughs, however, no support was found for Duchenne laughter having less physiological arousal than non-Duchenne laughter.

Hypothesis 2f. Voiced laughs will have higher inter-beat interval, skin conductance, temperature, and somatic activity arousal levels during laughs (Laugh) and lower arousal levels following laughs (Post Laugh) than non-Voiced laughs.

Voiced vs. non-Voiced laughs

Main effects for Laugh Kind were found in three of the four physiology measures: Inter-beat Interval $F(1, 36) = 7.25, p < .05, \eta^2 = .15$; Skin Conductance $F(1, 36) = 5.42, p < .05, \eta^2 = .15$; and Somatic Activity $F(1, 36) = 10.53, p < .005, \eta^2 = .22$. In each case, Voiced laughter was associated with greater arousal than non-Voiced laughter: Inter-beat Interval Means: Voiced = .20, non-Voiced = .16 (as discussed previously, Inter-beat Interval values were reverse scored so that larger values indicate higher arousal—i.e., smaller Inter-beat Intervals), Skin Conductance Means: Voiced = -.010, non-Voiced = -.032, and Somatic Activity Means: Voiced = .17, non-Voiced = .15.

Laugh Kind X Data Bins interactions were found for Inter-beat Interval ($F[2, 72] = 3.49, p < .05, \eta^2 = .07$) and Somatic Activity ($F[2, 72] = 6.35, p < .05, \eta^2 = .14$), but not for Temperature, $F[2, 72] = .138, p > .05$, or Skin Conductance, $F[2, 72] = .59, p > .05$. As predicted, Voiced laughs had greater Inter-beat Interval and Somatic Activity arousal than non-Voiced laughs during laughs (Inter-beat Interval Means: Voiced = .29, non-Voiced = .21, $t(39) = -4.78, p < .001$; Somatic Activity Means: Voiced = .25, non-Duchenne = .18, $t(39) = -5.44, p < .001$). Voiced laughs, however, were not found to have lower levels of arousal than non-Voiced laughs Post Laugh (Inter-beat Interval Means: Voiced = .12, non-Voiced = .10, $t[39] = -.87, p = NS$; Somatic Activity Means: Voiced = .12, non-Voiced = .14, $t[39] = 1.08, p = NS$).

Therefore, the hypothesis that Voiced laughs will have higher inter-beat interval, skin conductance, temperature, and somatic activity arousal levels during laughs (Laugh) and lower arousal levels following laughs (Post Laugh) than non-Voiced laughs was partially supported in two of four physiology measures. As predicted, Voiced laughter had higher inter-beat interval and somatic activity (but not skin conductance or temperature) arousal during laughs than non-Voiced laughs. Following laughs, however, no support was found for Voiced laughter having less physiological arousal than non-Voiced laughter.

Summary of findings comparing patterns of inter-beat interval, skin conductance, temperature, and somatic activity arousal between different kinds of laughs (Hypotheses 2d, 2e, 2f)

Antiphonal, Duchenne, and Voiced laughs had greater physiological arousal (somatic activity and inter-beat interval) during laughs than non-Antiphonal, non-Duchenne, and non-Voiced laughs. Also, Antiphonal laughs were found to have greater skin conductance arousal during laughs than non-Antiphonal laughs. No differences were found between Duchenne vs. non-Duchenne and Voiced vs. non-Voiced laughs in skin conductance arousal. Also, no differences were found between laughs based on Temperature.

Hypothesis 2g. Antiphonal laughs will have lower finger pulse amplitude, finger pulse transit time, and ear pulse transit time arousal during laughs (Laugh) and following laughs (Post Laugh) compared to non-Antiphonal laughs.

Antiphonal vs. non-Antiphonal Laughter

A main effect for Laugh Kind was found for Finger Pulse Amplitude ($F[1, 59] = 4.51, p < .05, \eta^2 = .07$); Antiphonal laughter had greater Finger Pulse Amplitude arousal than non-Antiphonal laughter (Means: Antiphonal = .14, non-Antiphonal = .13). No main effects for Laugh Kind were found for Finger Pulse Transit Time, $F[1, 59] = 2.15, p > .05$, or Ear Pulse Transit Time, $F[1, 59] = .99, p > .05$.

An interaction between Laugh Kind and Laugh Timing was found for Ear Pulse Transit Time, $F[2, 118] = 6.79, p < .005, \eta^2 = .10$; however, no differences between means were found during Laughs (Means: Antiphonal = -.05, non-Antiphonal = -.03; $t[62] = .95, p = NS$) or Post laughs (Means: Antiphonal = .03, non-Antiphonal = -.01, $t[62] = -2.19, p = NS$). No Laugh Kind X Laugh Timing interactions were found for Finger Pulse Amplitude, $F[2, 118] = 1.80, p > .05$; or Finger Pulse Transit Time, $F[2, 118] = 1.03, p > .05$.

Therefore, the hypothesis that Antiphonal laughs will have less finger pulse amplitude, finger pulse transit time, and ear pulse transit time arousal during laughs (Laugh) and following laughs (Post Laugh) compared to non-Antiphonal laughs was not supported.

Hypothesis 2h. Duchenne laughs will have less finger pulse amplitude, finger pulse transit time, and ear pulse transit time arousal during laughs (Laugh) and following laughs (Post Laugh) compared to non-Duchenne laughs.

Duchenne vs. non-Duchenne laughter

No main effects for Laugh Kind were found for Finger Pulse Amplitude, $F[1, 26] = .62, p > .05$; Finger Pulse Transit Timing, $F[1, 26] = 2.24, p > .05$; or Ear Pulse Transit Time, $F[1, 26] = 2.36, p > .05$. Also, no interactions between Laugh Kind and Laugh Timing were found for Finger Pulse Amplitude, $F[2, 52] = .33, p > .05$; Finger Pulse Transit Time, $F[2, 52] = .12, p > .05$; or Ear Pulse Transit Time, $F[2, 52] = 1.38, p > .05$.

Therefore, the hypothesis that Duchenne laughs will have less finger pulse amplitude, finger pulse transit time, and ear pulse transit time arousal during laughs (Laugh) and following laughs (Post Laugh) compared to non-Duchenne laughs was not supported.

Hypothesis 2i. Voiced laughs will have less finger pulse amplitude, finger pulse transit time, and ear pulse transit time arousal during laughs (Laugh) and following laughs (Post Laugh) compared to non-Voiced laughs.

Voiced vs. non-Voiced laughter

No main effects for Laugh Kind were found for Finger Pulse Amplitude, $F[1, 36] = .30, p > .05$; Finger Pulse Transit Time, $F[1, 36] = .46, p > .05$; or Ear Pulse Transit Time, $F[1, 36] = 1.00, p > .05$. Also, no interactions between Laugh Kind and Laugh Timing were found for Finger Pulse Amplitude, $F[2, 72] = .44, p > .05$; Finger Pulse Transit Time, $F[2, 72] = 2.05, p > .05$; or Ear Pulse Transit Time, $F[2, 72] = .024, p > .05$.

Therefore, the hypothesis that Voiced laughs will have less finger pulse amplitude, finger pulse transit time, and ear pulse transit time arousal during laughs (Laugh) and following laughs (Post Laugh) compared to non-Voiced laughs was not supported.

Summary of findings comparing patterns of finger pulse amplitude, finger pulse transit time, and ear pulse transit time arousal between different kinds of laughs (Hypotheses 2g, 2h, 2i)

No support was found for Antiphonal, Duchenne, and Voiced laughs having lower levels of physiological arousal in finger pulse amplitude, finger pulse transit time, or ear pulse transit time following laughs than non-Antiphonal, non-Duchenne, and non-Voiced laughs, respectively.

Aim #2: Summary of findings

Antiphonal, Duchenne, and Voiced laughs were more strongly associated with self-reported emotion becoming more positive during and following laughs than non-

Antiphonal, non-Duchenne, and non-Voiced laughs, respectively. Antiphonal, Duchenne, and Voiced laughs were also found to have greater physiological arousal (somatic activity and inter-beat interval) during laughs than non-Antiphonal, non-Duchenne, and non-Voiced laughs, respectively. Also, Antiphonal laughs were found to have greater skin conductance arousal during laughs than non-Antiphonal laughs. No support was found for Antiphonal, Duchenne, and Voiced laughs having lower levels of physiological arousal following laughs than non-Antiphonal, non-Duchenne, and non-Voiced laughs, respectively.

Aim #3: To determine individual differences in the use of laughter based on sex, age, and marital satisfaction

Hypothesis 3a. Wives will laugh more than husbands.

Contrary to prediction, no main effect was found for Spouse when using Total Laugh Frequency as the dependent variable, $F(1, 238) = 1.84, p > .05$. Therefore, the hypothesis was not supported.

Hypothesis 3b. Wives will use proportionately more Antiphonal laughs than husbands.

Contrary to prediction, no main effect was found for Spouse using Proportion of Antiphonal Laughs as the dependent variable, $F(1, 238) = 2.98, p > .05$. Therefore, the hypothesis that wives will use proportionately more Antiphonal laughs than husbands was not supported.

Hypothesis 3c. Older couples will use proportionately more Antiphonal, Duchenne, and Voiced laughs than middle-aged couples.

Main effects for Age were found for all three kinds of laughs: Proportion of Antiphonal Laughs $F(1, 238) = 7.80, p < .01, \eta^2 = .03$; Proportion of Duchenne Laughs, $F(1, 238) = 7.00, p < .01, \eta^2 = .03$, and Proportion of Voiced Laughs, $F(1, 238) = 12.64, p < .001, \eta^2 = .05$. Middle-aged couples used proportionately more Antiphonal laughter than older couples (Means: Middle-aged = .38, Older = .84); and older couples used proportionately more Duchenne (Means: Middle-aged = .69, Older = .81) and Voiced (Means: Middle-aged = .61 vs. Older = .76) laughs than middle-aged couples.

An Age X Marital Satisfaction interaction was found for Proportion of Duchenne Laughs, $F(1, 238) = 7.97, p < .05, \eta^2 = .03$. Middle-aged unsatisfied couples had lower proportions of Duchenne laughs than middle-aged satisfied couples (Means: Middle-aged/Unsatisfied = .57, Middle-aged/Satisfied = .82; $t[126] = -3.94, p < .001$), older satisfied couples (Means: Middle-aged/Unsatisfied = .57, Older/Satisfied = .82; $t[144] = -4.24, p < .001$), and older unsatisfied older couples (Means: Middle-aged/Unsatisfied = .57, Older/Unsatisfied = .80; $t[117] = -3.31, p < .001$). No other Age X Marital Satisfaction interactions were found.

Therefore, the hypothesis that older couples will use proportionately more Antiphonal, Duchenne, and Voiced laughs than middle-aged couples was supported for Duchenne and Voiced, but not Antiphonal laughs. To the contrary, middle-aged couples

used proportionately more Antiphonal laughs than older couples with middle-aged/satisfied couples primarily contributing to this difference.

Hypothesis 3e. Satisfied couples will laugh more than unsatisfied couples.

A main effect for Marital Satisfaction was found using Total Laugh Frequency as a dependent variable, $F(1, 238)=5.634, p < .05, \eta^2 = .02$. Satisfied couples laughed more than unsatisfied couples (Means: Satisfied = 10.47, Unsatisfied = 7.98). An Age X Marital Satisfaction interaction (which was also reported above under the heading “Age difference findings not predicted”) was found, $F(1, 238) = 4.46, p < .05, \eta^2 = .02$; middle-aged satisfied couples laughed more than the other three groups of couples: namely, middle-aged unsatisfied couples (Means: Middle-aged/Satisfied = 14.31, Middle-aged/Unsatisfied = 7.34; $t[126] = 4.07, p < .001$), older unsatisfied couples (Means: Middle-aged/Satisfied = 14.31, Older/Unsatisfied = 7.98; $t[91] = 3.09, p < .005$), and older satisfied couples (Means: Middle-aged/Satisfied = 14.31, Older/Satisfied = 8.17; $t[118] = 3.79, p < .001$). Therefore, satisfied couples laughed more than unsatisfied couples with satisfied middle-aged couples primarily contributing to this difference.

Hypothesis 3f. Satisfied couples will use proportionately more positive laughs (Antiphonal, Duchenne, and Voiced laughs) than unsatisfied couples.

Main effects for Marital Satisfaction were found for Proportion of Duchenne Laughs, $F(1, 238) = 6.996, p < .01, \eta^2 = .04$, and Proportion of Voiced Laughs, $F(1, 238) = 12.642, p < .001, \eta^2 = .07$. Satisfied couples used proportionately more Duchenne and Voiced laughs than unsatisfied couples (Duchenne Means: Satisfied = .82, Unsatisfied = .68; Voiced Means: Satisfied = .77, Unsatisfied = .60). No main effect for Marital Satisfaction was found for Proportion of Antiphonal Laughs, $F(1, 238) = 1.20, p > .05$. Therefore, the hypothesis that satisfied couples will use proportionately more positive laughs than unsatisfied couples was supported for Duchenne and Voiced laughs, but not Antiphonal laughs.

Aim # 3: Summary of findings

Middle-aged couples laughed more than older couples; and satisfied couples laughed more than unsatisfied couples with middle-aged satisfied couples primarily contributing to these differences. No differences in the use of laughter were found between husbands and wives. As predicted, older couples used proportionately more Duchenne and Voiced laughs than middle-aged couples; however, middle-aged couples used proportionately more Antiphonal laughs than older couples. Satisfied couples used proportionately more Duchenne and Voiced laughs than unsatisfied couples. No differences between satisfied and unsatisfied couples were found in the use of Antiphonal laughter.

Discussion

Laughter is a complex and highly organized socio-emotional behavior display, involving the coordination of multiple emotional and physiological systems, each with a

different pattern of onset, direction of response (increases or decreases), strength of response, and offset. To understand the emotional and physiological structure of laughter, I examined behavioral, self-report, and physiological data collected while middle-aged and older married couples engaged in discussions of marital conflict. I focused on three kinds of laughs (Antiphonal, Duchenne, and Voiced), investigating the impact they have on the emotional and physiological structure of laughs. Finally, individual differences in the use of laughter were investigated based on spouse, age, and marital satisfaction.

What happens to people emotionally when they laugh?

In the present study, it was hypothesized that self-reported emotion would become more positive during laughs (Pre-Laugh vs. Laugh) and remain increased following laughs (Pre-Laugh vs. Post Laugh). This pattern is precisely what was found. Self-reported positive emotion increases tended to onset at the start of laughs, increase moderately during laughs, and remain elevated during the 10-seconds following laughs. The observation that increased positive emotion tended to occur during laughs and persist long after laughs had ended provides compelling support that a function of laughter is to impact emotional experience positively.

What happens to people physiologically when they laugh?

I predicted that physiological arousal during laughs (Pre-Laugh vs. Laugh) would increase for some measures (inter-beat interval, skin conductance, temperature, and somatic activity) and decrease for other measures (finger pulse amplitude, finger pulse transit time, and ear pulse transit time). These predictions were supported in five channels (somatic activity, inter-beat interval, skin conductance, finger pulse transit time, and ear pulse transit time) out of seven (support was not found in temperature or finger pulse amplitude). Laughs began with a sharp increase of somatic activity, followed one second later by the start of staccato breathing (i.e., quick, sharp, repeated breaths) and sharp increases in inter-beat interval arousal (i.e., smaller inter-beat intervals) and sharp decreases in ear pulse transit time arousal (i.e., slowed transit times). Two seconds after the start of laughs, finger pulse transit time arousal decreased (i.e., slowed transit times) sharply; and three seconds after the start of laughs, skin conductance arousal increased slightly. Temperature and finger pulse amplitude were unresponsive to laughs. The duration of staccato breathing varied depending on the duration of the laugh. End of laughs were defined by somatic activity returning to near pre-laugh levels. All of the measures that responded during laughter (with the exception of skin conductance) returned to near pre-laugh levels between five and seven seconds after staccato breathing ended. Skin conductance, however, remained elevated for fifteen seconds after staccato breathing ended. By demonstrating that these patterns of physiological activity were present in the naturalistic interactions of married couples discussing an area of disagreement, these findings support and extend prior research, which identified similar patterns in participants observing humorous film clips (e.g., Vlachopoulos, et al., 2009).

I also predicted that a function of laughter was to undo (Pre-Laugh vs. Post Laugh) pre-existing physiological arousal, leaving individuals more physiologically

relaxed following laughs than prior to laughs. This prediction was not supported. In fact, only one (ear pulse transit time) out of seven physiological responses had decreased arousal (i.e., transit times lengthened) following laughs. All other measures either did not change (inter-beat interval, temperature, somatic activity, finger pulse amplitude, finger pulse transit time, ear pulse transit time) or increased (skin conductance). These findings do not support the hypothesis that a function of laughter is to undo pre-existing states of physiological arousal. These findings were consistent across the three kinds of laughs.

It may be that the physiological responses associated with laughter contribute to the increasingly positive emotion reported by participants (see preceding section). Similar to people reporting feeling better emotionally after engaging in physical exercise, perhaps the burst of physiological activity associated with laughter causes increases in positive emotion. Establishing a causal link between physiology and emotion is beyond the scope of this study; however, preliminary support for this notion can be seen in the relative temporal patterns of emotional and physiological arousal. Specifically, increases in positive emotion began at the same time as increases in physiological arousal, suggesting that the two phenomena might be related.

Are Antiphonal, Duchenne, and Voiced laughs more strongly associated with increases in emotional and physiological activity during laughs (Pre-Laugh to Laugh) than non-Antiphonal, non-Duchenne, and non-Voiced laughs, respectively?

In the present study, three comparisons were made between kinds of laughs: Antiphonal laughs were compared to non-Antiphonal laughs; Duchenne laughs were compared to non-Duchenne laughs, and Voiced laughs were compared to non-Voiced laughs. It was predicted that during laughs Antiphonal, Duchenne, and Voiced laughs would have more positive self-reported emotion, higher physiological arousal levels in some measures (inter-beat interval, skin conductance, temperature, and somatic activity) and lower physiological arousal levels in other measures (finger pulse amplitude, finger pulse transit time, and ear pulse transit time) than non-Antiphonal, non-Duchenne, and non-Voiced laughs, respectively. These predictions were largely supported. Specifically, Antiphonal, Duchenne, and Voiced laughs had more positive self-reported emotion, and higher inter-beat interval and somatic activity arousal levels during laughs than non-Antiphonal, non-Duchenne, and non-Voiced laughs, respectively. Also, Antiphonal laughs had higher skin conductance arousal than non-Antiphonal laughs during laughs. No differences between kinds of laughs were found for temperature, finger pulse amplitude, finger pulse transit time, or ear pulse transit time. These findings support and extend previous findings that found self-reported emotion and physiological arousal to be higher for Antiphonal, Duchenne, and Voiced laughs compared to non-Antiphonal, non-Duchenne, and non-Voiced laughs, respectively (e.g., Bachorowski & Owren, 2001; Keltner & Bonanno, 1997; Smoski & Bachorowski, 2003).

Are self-reported emotion levels more positive during Antiphonal, Duchenne, and Voiced laughs (Pre-Laugh vs. Post Laugh) than during non-Antiphonal, non-Duchenne, and non-Voiced laughs, respectively?

In each of the three comparisons made between kinds of laughs (Antiphonal vs. non-Antiphonal, Duchenne vs. non-Duchenne, and Voiced vs. non-Voiced) it was predicted that Antiphonal, Duchenne, and Voiced laughs would be more effective than non-Antiphonal, non-Duchenne, and non-Voiced laughs, respectively, at causing self-reported emotion to become (Pre-Laugh vs. Post Laugh) more positive. As predicted, self-reported emotion was more positive following laughs (Pre-Laugh vs. Post Laugh) for Antiphonal, Duchenne, and Voiced laughs than non-Antiphonal, non-Duchenne, and non-Voiced laughs, respectively. These findings provide additional support for the theory that some laughs (Antiphonal, Duchenne, and Voiced laughs) are more effective at increasing positive emotions than others (non-Antiphonal, non-Duchenne, and non-Voiced laughs). However, an alternative explanation may be that self-reported emotions that became more positive caused an increase in Antiphonal, Duchenne, and Voiced laughs.

Antiphonal, Duchenne, and Voiced laughs: Three kinds of laughs or three indications of one kind of laugh?

The results found in all three comparisons between kinds of laughs (Antiphonal vs. non-Antiphonal, Duchenne vs. non-Duchenne, and Voiced vs. non-Voiced) were nearly identical to one another. This observation raises the question of whether Antiphonal, Duchenne, and Voiced laughs are, in fact, three different kinds of laughs or whether they might be better characterized as three different indications of the same kind of laugh. To address this possibility the amount of overlap between kinds of laughs was observed (see Table 1). If a very large proportion of laughs met criteria for more than one kind of laugh (Antiphonal, Duchenne, or Voiced), this would suggest that these qualities are measuring the same phenomenon. In support of the view that these are really three indications of the same kind of laugh, the vast majority of laughs that met criteria for one kind of laugh (Antiphonal, Duchenne, and Voiced) also met criteria for one or both of the other kinds of laughs. Specifically, nearly 98% of Antiphonal laughs also met criteria for Duchenne, Voiced, or both Duchenne and Voiced laughs; 88% of Duchenne laughs also met criteria for Antiphonal, Voiced, or both Antiphonal and Voiced laughs; and 90% of Voiced laughs also met criteria for Antiphonal, Duchenne, or both Antiphonal and Duchenne laughs. These extremely high rates of overlap between kinds of laughs suggest that Antiphonal, Duchenne, and Voiced laughter qualities may be best characterized as three ways of identifying the same kind of laugh.

Differences in laughter based on sex, age, and marital satisfaction

Sex. It was predicted in the present study that wives would laugh more, and use proportionately more Voiced laughs, than husbands. Contrary to prediction, however, sex differences in the use of laughter were not found. One possible explanation for these null findings is that, in the context of marital interaction, husband and wife communication patterns were highly influenced by one another, causing differences that would otherwise be apparent to become less so. In support of this explanation, the occurrence of laughter was highly correlated between husbands and wives, suggesting that husband and wife laughter patterns are closely related to one another. This observation also provides support for the contagious nature of laughter.

Sex differences in the use of laughter (i.e., women laughing more than men and women using proportionately more Antiphonal laughs than men) found in previous research were found either in the context of group social interactions between students on college campuses (Provine, 1993) or within dyadic interactions between friends and strangers (Bachorowski, Smoski, & Owen, 2001). Therefore, the strength of the attachment bonds between people, whether strangers, friends, or spouses, may influence how similar or dissimilar patterns of laughter are between people during interpersonal interactions. To test this possibility, future research is needed to observe individual patterns of laughter across different interpersonal relationships.

Age. Socio-Emotional Selectivity Theory (Carstensen, 1992) posits that as people age, emotion related goals (e.g., experiencing positive emotions and investing time in close relationships) take on proportionately more importance than other kinds of goals (e.g., knowledge acquisition and expansion of social networks). Based on this theory, it was predicted in the present study that older couples would laugh more, and use proportionately more Antiphonal, Duchenne, and Voiced laughs, than middle-aged couples. Support for this hypothesis was mixed. On the one hand, older couples had higher proportions of Duchenne and Voiced laughs than middle-aged couples. On the other hand, middle-aged couples (particularly satisfied middle-aged couples) laughed more, and used proportionately more Antiphonal laughs, than older couples.

A possible explanation for middle-aged couples laughing more than older couples may be related to the global diminution in the amplitude of autonomic responding to both emotional and non-emotional stimuli as people age. Previous research found that during marital discussion of conflict, middle-aged couples were more physiologically aroused than older couples (Levenson & Carstensen, 1993). Laughter involves physiological arousal. Therefore, this general pattern of decreased arousal for older couples compared to middle-age couples may be responsible for differences in the frequency of laughs. This explanation, however, does not account for why middle-aged couples used proportionately more Antiphonal laughs than older couples.

Another possible explanation is that middle-aged couples used laughter for functionally different reasons than older couples. As mentioned before, previous research found that marital discussions of conflict tend to be more physiologically arousing for middle-aged couples than older couples (Levenson & Carstensen, 1993). Therefore, perhaps middle-aged couples used laughter for emotion regulation purposes more than older couples, leading to a greater frequency of laughs. Additional research, however, is needed to test this notion. Moreover, this explanation also fails to account for middle-aged couples using proportionately more Antiphonal laughter than older couples.

Finally, a third possibility is that middle-aged couples were more demonstrative of their positive feelings towards one another through laughter than older couples. In support of this possibility, in the present study middle-aged couples who were satisfied in their marriages laughed more than the other three groups of couples (unsatisfied middle-aged couples and both satisfied and unsatisfied older couples). Also, middle-age couples used proportionately more Antiphonal laughter—a kind of laugh found by previous research to communicate shared positive regard and openness to continued communication (Smoski, 2005)—than older couples. These findings suggest that middle-aged couples may have been more directly affectionate in their use of laughter with one

another than older couples. Perhaps laughter in older couples has a larger humor component, which might explain their larger proportion of Duchenne and Voiced laughs compared to middle-aged couples. Future research is needed to look more closely at how laughs are used by middle-aged and older married couples.

Marital Satisfaction. It was predicted that satisfied married couples would laugh more, and use proportionately more Antiphonal, Duchenne, and Voiced laughs, than unsatisfied couples. This prediction was largely supported. Satisfied couples laughed more, and used proportionately more Duchenne and Voiced laughs, than unsatisfied couples; however, no differences were found between satisfied and unsatisfied couples in the use of Antiphonal laughter. Also, satisfied couples' self-reported emotion associated with laughs was more positive for satisfied than dissatisfied couples. These findings provide strong support for the theory that laughter (especially Duchenne and Voiced laughs) is associated with marital satisfaction. One possible explanation is that people in satisfying relationships share more positive emotions, making it more likely for people to laugh and, in particular, to use Duchenne and Voiced laughs. Another possibility is that large amounts of laughter and large proportions of Duchenne and Voiced laughs cause relationships to become more satisfying. Laughter is believed to play an important role in the facilitation of communication and the maintenance of relationship bonds of attachment, which are believed to be important components of marital satisfaction. To address the causal direction of these relationships future longitudinal research is needed to test how patterns of laughter change as marital satisfaction changes.

Strengths and Weaknesses

The present study is unique in many ways. Strengths of the study include investigating laughter in a highly naturalistic and interpersonal setting while making comparisons between husbands and wives, middle-aged and older couples, and satisfied and unsatisfied couples. Three different kinds of data were obtained to gain a rich description of laughter: observational, self-report, and physiological arousal. Seven physiological signals were measured to sample broadly from major organ systems related to emotional arousal; namely, cardiovascular, thermoregulatory, electrodermal, and muscular (somatic). Continuous second by second self-reports of emotional experience were obtained. These continuous data allowed assessment of the relative onset and offset, direction of response, and intensity of each measure, revealing a complex and highly organized emotional and physiological profile of laughter. Three different kinds of laughter (Antiphonal, Duchenne, and Voiced) were identified and investigated regarding the impact they have on patterns of self-reported emotional and physiological arousal for Actors and Partners. Finally, individual differences in the amount of laughter were investigated based on spouse, age, and marital satisfaction.

In terms of weaknesses, without longitudinal data, it was not possible to determine whether age differences in the use of laughter found in the present study were due to age or cohort. Cohort differences are a viable explanation for found differences between age groups because middle-aged and older married couples came of age in different social climates occurring against a backdrop of very different nation wide events and trends. For example, middle-aged couples in this sample were young adults during

the sexual revolution of the 1960's, which may have caused them to become more expressive with their feelings, including the use of laughter. Older couples were young adults during the Industrial Revolution and WWII, times that were relatively conservative compared to the 1960's.

Future Directions

The findings of the present study raise many additional questions for future research. Longitudinal research is needed to determine whether found difference between middle-aged and elderly couples are due to age difference or cohort differences. Such research may also help determine the direction of causation and the mechanisms by which laughter and relationship satisfaction influence one another.

It is unclear whether the patterns of physiological arousal associated with laughter observed in the present study are unique to laughter or whether they are shared by other human responses to both emotionally and non-emotionally arousing stimuli. To address this question, future research is needed to compare the physiological response associated with laughter with other "respiratory" states such as sneezing, yawning, and crying and with other emotional and emotion related states such as joy, humor, and exhilaration.

Finally, the kinds of laughs investigated in the present study make up only a small proportion of the many kinds of laughs that exist. Future research is needed to investigate other kinds of laughs in the context of marriage, such as laughs that accompany speech and laughs that accompany more negative emotions, such as contempt and belligerence.

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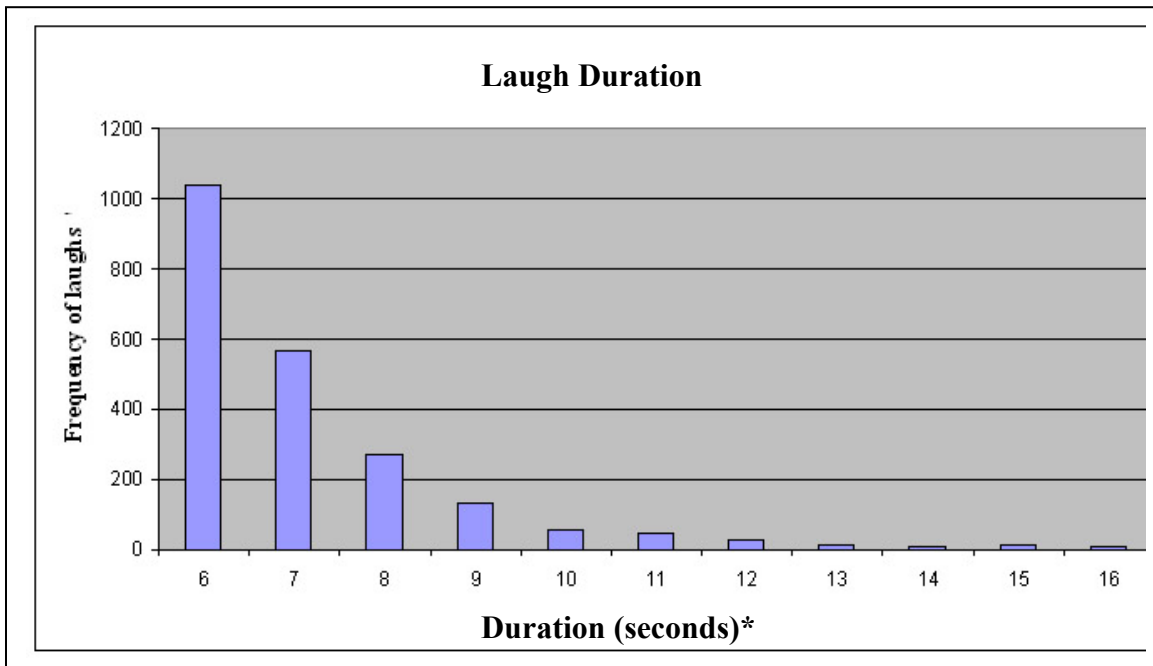
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Figure 1.



* Laughs between 17 and 187 seconds rarely occurred; therefore, they were not included in this histogram.

Figure 2.

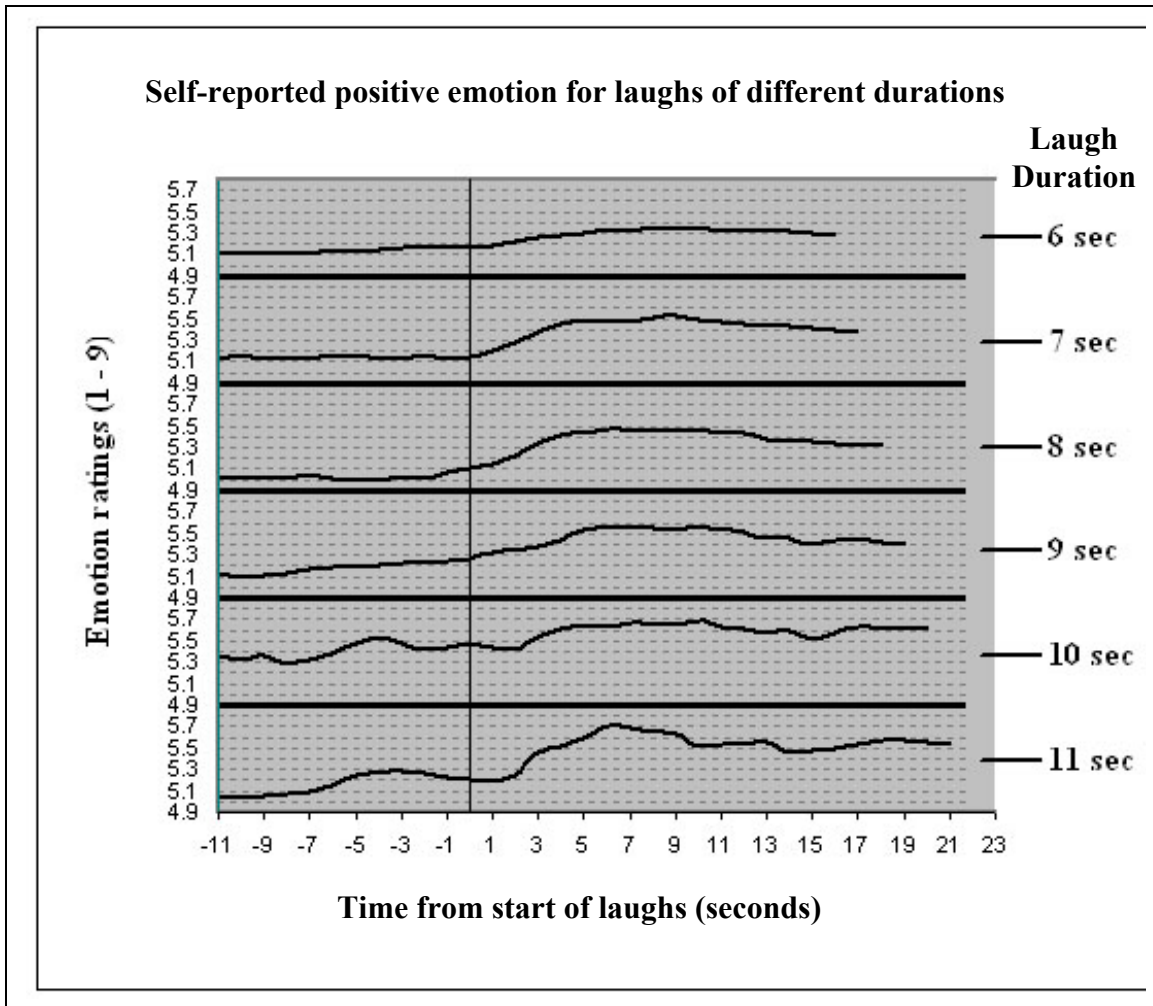
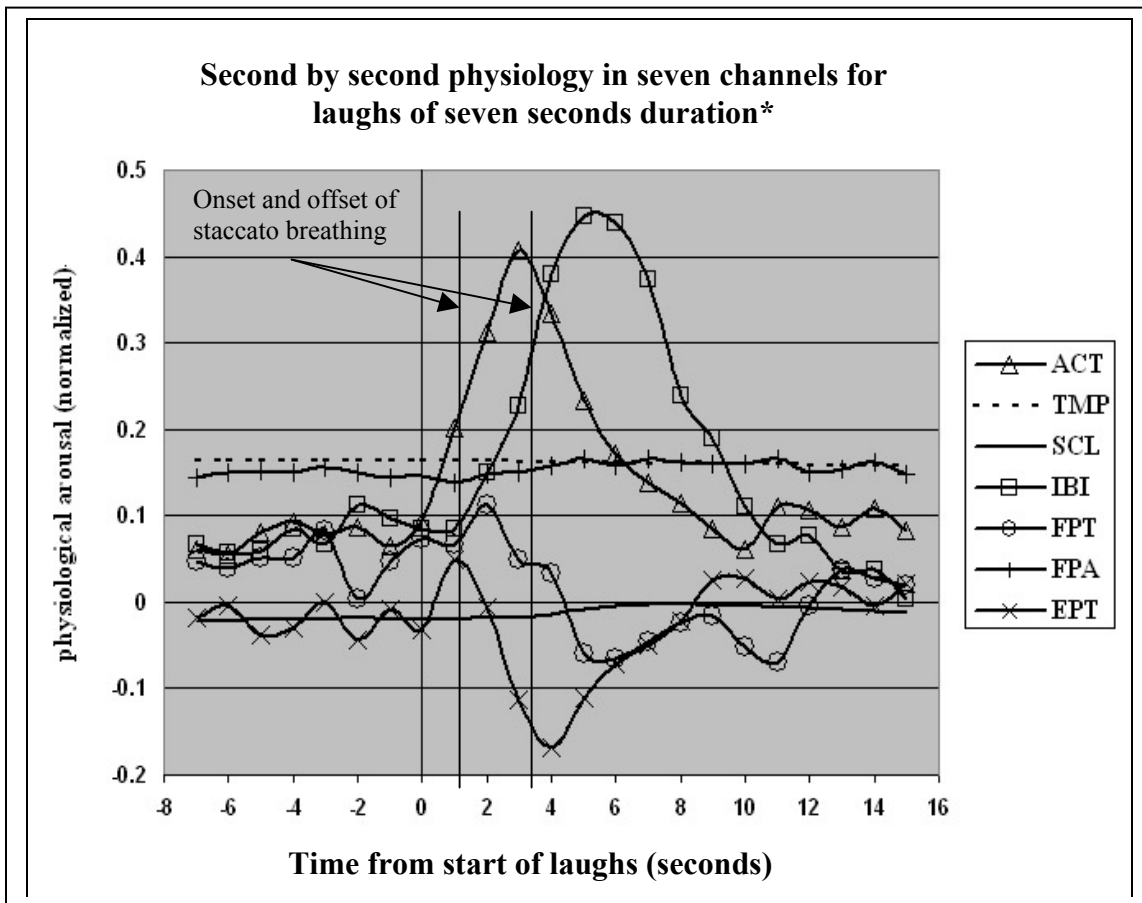


Figure 3.



* *Act = Somatic Activity, TMP = Temperature, SCL=Skin Conductance, IBI=Inter-beat Interval, FPT=Finger Pulse Transit Time, FPA=Finger Pulse Amplitude, EPT=Ear Pulse Transit Time.*

Figure 4.

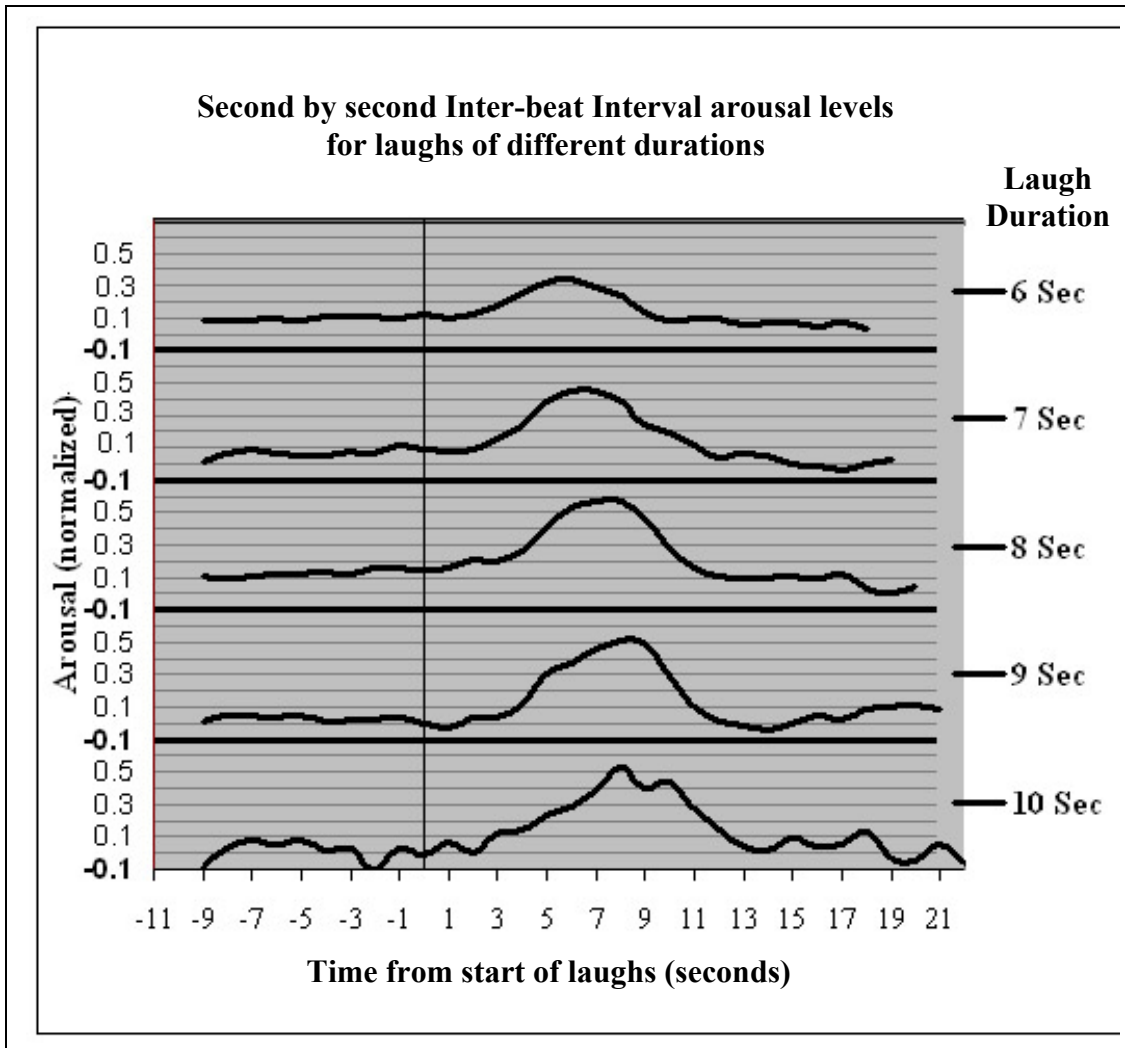


Figure 5.

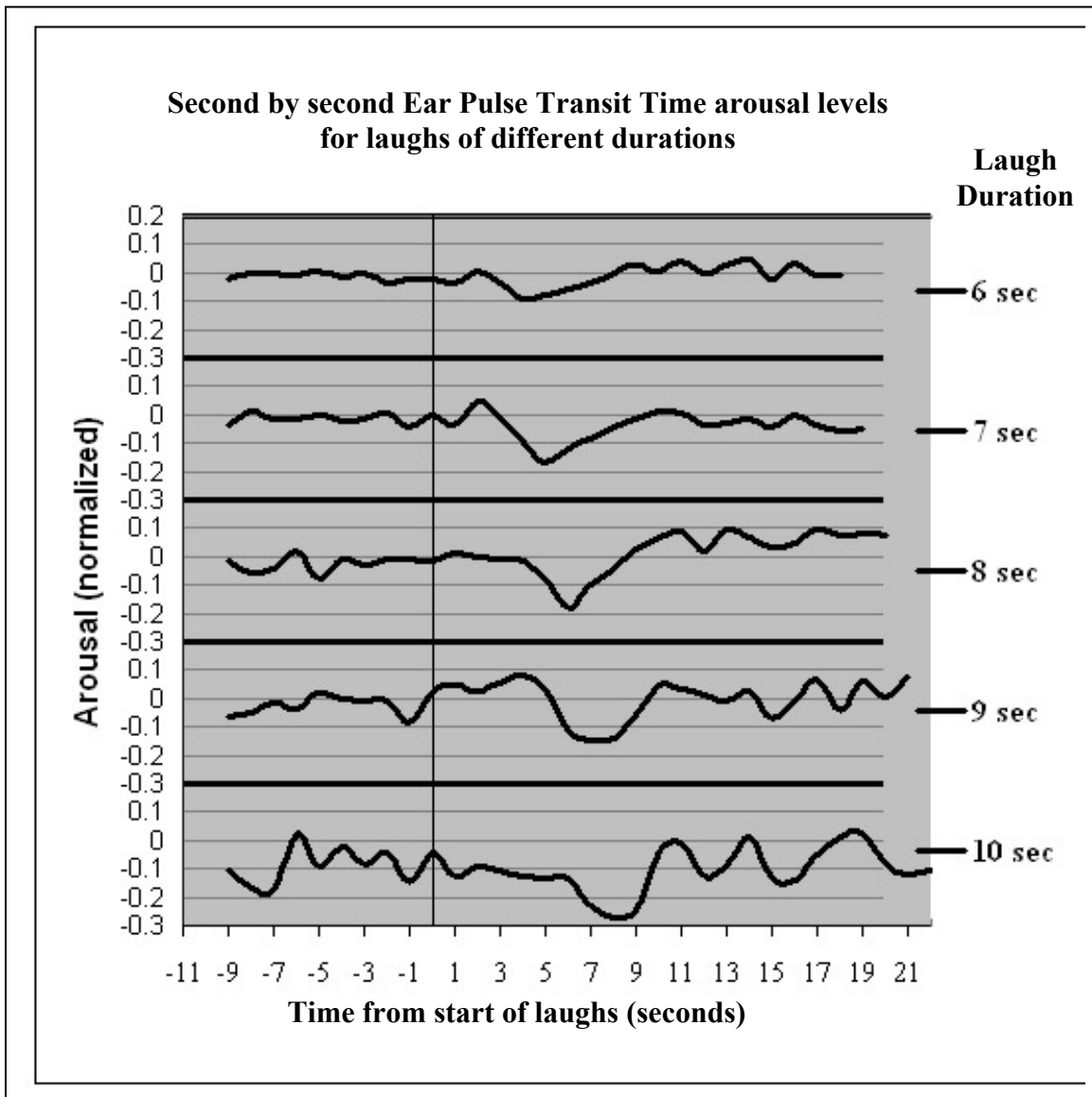


Table 1.

Frequency and percentage of overlap between kinds of laughs

	Quantity of overlapping kinds of laughs			Total
	None	One other kind	Two other kinds	
Duchenne	218	905	759	1882
<i>% of Total Duchenne</i>	<i>11.6</i>	<i>48.1</i>	<i>40.3</i>	<i>100</i>
Voiced	155	775	759	1689
<i>% of Total Voiced</i>	<i>9.2</i>	<i>45.9</i>	<i>44.9</i>	<i>100</i>
Antiphonal	19	226	759	1004
<i>% of Total Antiphonal</i>	<i>1.9</i>	<i>22.5</i>	<i>75.6</i>	<i>100</i>