Subjective and physiological reactivity to flight in people with fear of flying

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Chapter 7

Synchronous change in subjective and physiological reactivity during flight as an indicator of treatment outcome for aviophobia: a longitudinal study with 3-year follow-up

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submitted

ABSTRACT

Emotion can be seen as the organizing process that coordinates response systems to deal effectively with challenges and opportunities. Synchronous change in subjective and physiological reactivity is regarded as an indication of this organizing process. Synchrony is expected to increase with the intensity of emotional stimuli. Conversely, adaptive emotional functioning could be indicated by progressive synchrony upon increasing demands, and the magnitude of synchrony could be an indication of progress during therapy. We examined whether synchronous change in subjective and physiological reactivity over repeated exposures increased from watching a flight video through simulated flight to actual flight, and whether the magnitude of synchronous change predicted favourable short- and long-term treatment outcome within a group of 77 aviophobic participants during CBT. Results did not show a relationship between the intensity of the phobic stimuli and the magnitude of synchronous change in subjective and physiological reactivity. Moreover, synchronous change across both response systems did not predict treatment outcome. The results provide only weak support for the functionalistic view that successful treatment of anxiety disorders is indicated by synchronous change across emotional response systems. The relationship between these systems is likely to be affected by many intervening variables including higher order cognitive processes.

INTRODUCTION

Emotions enable action for survival (Frijda, 1986; Lang & McTeague, 2009). Within this functionalist view, coherence within and between biological systems (ANS, motor programs, vocalization, facial expression) facilitates coordinated responses supporting adaptive behaviour and effective communication. Coherence between biological systems is expected to increase with emotional intensity (Hollenstein & Lanteigne, 2014). Coherence can be measured as concordance or as synchrony. Whereas concordance refers to joint activation of the subsystems, synchrony refers to correlated changes in their activation over time. These temporal changes can be either in concert or in the opposite direction. Albeit intuitively appealing, evidence for concordance and synchrony is weak (Benoit Allen, Allen, Austin, Waldron, & Ollendick, 2015; Hollenstein & Lanteigne, 2014).

The tripartite model of Lang states that the emotion of fear is expressed in three loosely coupled domains: affective language, overt behaviour, and physiological reactivity (Lang, 2014; Lang & McTeague, 2009). Organized and coordinated activity between these response systems enables the individual to deal effectively with challenges (and opportunities), according to the evolutionary/functionalistic view of emotions (James, 1884; Levenson, 2014b). Emotion can be seen as the organizing process that coordinates these different systems to prepare the individual for optimal and effective response (Levenson, 2014b). When the individual is faced with increasing demands the coordinated co-activation of multiple response systems would seem even more important. Response coherence would thus be expected to increase with increasing emotional intensity. Conversely, adaptive emotional functioning could be indicated by proper and progressive response coherence upon increasing demands. If so, the magnitude of coherence could be an indication of progress during therapy. As early as 1974 Hodgson and Rachman (1974) proposed that successful treatment of anxiety disorders should be indicated by synchronous change across all three domains of the tripartite model.

A decade later several studies assessing this proposition with agoraphobic patients were published; the mixed results raised more questions than answers. Interpretation was hampered by small sample sizes and doubts about the reliability and validity of heart rate measurements, but most of all by different operationalization of concordance and synchrony. In a series of publications (Michelson, 1984; Michelson & Mavissakalian, 1985; Michelson, Mavissakalian, & Marchione, 1985) Michelson and colleagues reported that subjects showing greater HR/SUD concordance were less symptomatic than those showing less concordance. A few years later the same authors reported better outcomes, both post-treatment and at 3-month follow-up, with participants showing synchronous change during treatment. Here, synchronous change was defined as at least one unit decrease in HR and SUD during treatment (Michelson et al., 1990). Mavissakalian (1987) followed 22 agoraphobic patients in a 12-week study involving in-vivo exposure (flooding). Both concordance and synchrony analysis revealed no relationship with outcome. Vermilyea et al. (1984) assessed 28 agoraphobic patients during a pre-, mid-, and post-treatment walk. Patients were dichotomised: synchronous patients were defined as those who showed concordant change in HR and SUD across at least two out of three walks. Treatment responders showed synchronous changes as often as desynchronous changes. A trend emerged showing treatment non-response (n=5) to have a desynchronous pattern. This trend was lost at 6-month follow-up (Craske, Sanderson, & Barlow, 1987).

A few years later Beckham et al. (1990) reported a positive relationship between HR and SUD scores five minutes after take-off and five minutes prior to landing, but not upon airport arrival, prior to take-off and directly after landing, with 14 aviophobic participants during a post-treatment flight. Synchrony was investigated over the five measurement occasions for each subject separately. A median split was done on the synchrony measures for the twelve subjects with positive correlations. Subjects with high covariation between HR and SUD showed a significantly greater improvement in their Fear of Flying score between pre- to post-flight than subjects with less covariation. Finally, no correlation between SUD and HR was found with 21 driving phobic patients during three driving sessions (Alpers, Wilhelm, & Roth, 2005), while a significant positive synchronous change between SUD fear and HR was reported with six of 10 claustrophobic patients during six exposure sessions (Alpers, 2008). However, the authors failed to relate these synchronous changes to outcome.

Over all, very few studies have reported evidence of synchrony, despite the recent growth of interest in the relationship between emotional expression and patterns of ANS activity (Hollenstein & Lanteigne, 2014; Levenson, 2014a). This might be caused by the generally low intensity and low ecological validity of the stimuli used in most laboratory studies (Hollenstein & Lanteigne, 2014). Laboratory stimuli are essentially artificial, and quite often low in intensity. Ethical constraints limit the magnitude and type of stimuli available in experimental studies. The few studies that did report coherence were all done in vivo with realistic stimuli having high intensity (Alpers, 2008; Beckham et al., 1990; Ekeberg, Kjeldsen, Greenwood, & Enger, 1990; Nesse et al., 1985). It seems that, to find synchrony and relate it to treatment outcome, more intense stimuli are needed.

Phobias might be a good starting point, as anxiety-inducing stimuli in real life generally generate intense fear responses in phobic patients.

Current Study: hypotheses

In the present study we first assessed the notion that synchronous change in subjective and physiological reactivity increases with the intensity and ecological validity of emotional stimuli. We observed a clinical sample of 77 aviophobic individuals during repeated exposure to a flight-anxiety inducing video (low intensity), to a professional flight simulator (medium intensity), and during actual flight (high intensity). Based on previous research (Busscher, van Gerwen, Spinhoven, & de Geus, 2010) we expected participants to show subjective fear responses but minimal physiological reactivity to the low intensity artificial video stimuli, resulting in minimal synchronous change in the two response systems. With the increasing ecological validity and intensity of the anxiety-inducing phobic stimuli during simulated flight and actual flight we expected increased reactivity in the two response systems paired to increased synchronous change in this reactivity over repeated exposures. Second, we assessed whether the magnitude of synchronous change predicted short- and long-term treatment outcome. Based on the assumption of Hodgson and Rachman (1974) that successful treatment of anxiety disorders should be indicated by synchronous change, we expected participants with more synchronous change in the two response systems during treatment to show lower flight anxiety at the end of treatment and three year after treatment than participants with less synchronous change during treatment, and we also expected them to have engaged in more actual flights.

MATERIAL AND METHODS

Participants

The 77 participating adults (42 women) with an average age of 40.5 (SD 11.1) in this study were individuals who applied for treatment to overcome their Fear of Flying (FOF). Some participants were referred by health care agencies, health care professionals and company health programs, although most were self-referrals. Inclusion criteria were a good understanding of the Dutch language and no flight scheduled within 5 weeks of start of treatment. Exclusion criteria were current use of cardioactive medication like β blockers, pharmacotherapeutic medication and a concurrent panic disorder of such severity, according to the treating psychotherapist, that it would seriously interfere with the treatment. Airline personnel were also excluded from this study. Written informed consent was obtained from all participants previous to the diagnostic process. The local medical ethics committee approved the research protocol.

MEASURES

Subjective Units of Distress (SUD)

The Subjective Units of Distress scale was used to examine to what extent participants were anxious at various moments. Participants had to indicate their perceived anxiety on a scale from 1 (totally relaxed) to 10 (extremely anxious) (Wolpe, 1973).

Visual Analogue Flight Anxiety Scale (VAFAS)

The single-item Visual Analogue Flight Anxiety Scale was used to examine to what extent participants were anxious about flying. The one-tailed scale ranges from 0 (no flight anxiety) to 10 (terrified or extreme flight anxiety) (Nousi, Van Gerwen, & Spinhoven, 2008).

Physiological recordings

Heart Rate (HR), Respiratory Sinus Arrhythmia (RSA) and the Pre-Ejection Period (PEP) were recorded using the VU-AMS (version 4.6, Vrije Universiteit Amsterdam, The Netherlands; www.vu-ams.nl). The VU-AMS is a lightweight ambulatory device that unobtrusively and continuously performs an electrocardiogram (ECG) and impedance cardiogram (ICG) by means of six Ag-AgCl electrodes attached to the torso region (De Geus, Willemsen, Klaver, & van Doornen, 1995; Willemsen, De Geus, Klaver, Van Doornen, & Carrol, 1996). The instrument has an event marker and an inbuilt vertical accelerometer, whose output can be used to select movement-free periods for analysis. Automatic scoring of RSA and PEP was checked by visual inspection of the entire epoch. Details on the VU-AMS, scoring of the target variables, reliability and validity are described in detail elsewhere (Goedhart, Kupper, Willemsen, Boomsma, & de Geus, 2006; Riese, 2003). RSA is considered a measure of parasympathetic activity (Berntson et al., 1994), and PEP a measure of sympathetic activity (Sherwood et al., 1990). HR can be considered the resultant of both control systems. Fear responses are characterized by increases in HR, a decrease in RSA and shortening of the PEP.

Treatment

Participants in this study followed a highly standardized treatment program for fear of flying at the VALK foundation in The Netherlands. This institution is a joint enterprise of the Clinical Psychology Department at Leiden University with Amsterdam's Schiphol Airport and several Dutch airlines. It specializes in fear-related problems, especially fear of flying. The fear of flying program starts with a thorough diagnostic assessment, including pre-treatment phobia and flight-anxiety measurements, followed by a maximum of four individual 1-hour therapeutic sessions, covering general information on factors relevant to fear and anxiety, relaxation and breathing techniques, and coping skills. Claustrophobia, acrophobia, traumatic transportation accidents and traumatic social events were addressed where applicable. Participants started a two-day cognitive-behaviour group treatment (CBGT) five weeks after diagnostic assessment. CBGT groups consisted of a minimum of five to a maximum of eight participants, a therapist and an airline pilot. The first day of group treatment focused on psycho-education and technical information on flying. The second day focused on exposure and included two flights in a full motion cabin flight simulator normally used for flight safety training for cabin crew. The day ended with maximal in vivo exposure during guided return flights of at least one hour each on a commercial airliner. Details on therapeutic procedure have been published elsewhere (Van Gerwen, Spinhoven, & Van Dyck, 2006).

Data Collection Procedure

Before the start of the diagnostic assessment, and five weeks later before the start of the two-day CBGT, participants viewed an anxiety inducing flight-video, preceded by a neutral video, both lasting six minutes. The flight video consisted of a flight safety demonstration video of a Boeing 747 followed by some video shots of a landing Boeing 737. Subjective units of distress (SUD) were measured directly after neutral and flight video presentations. Using a visual display of the output of an inbuilt vertical accelerometer of the physiological recording device, we identified movement-free and artifact-free periods that lasted at least 5 minutes during flight-video and neutral video.

On the second day of CBGT, SUDs were collected directly after both simulator flights. Five-minute artifact-free periods within the simulated flights were selected for the physiological recording. During the two actual flights, SUDs were collected during taxi-out of the first flight and during taxi-in of the second flight. Again, movement-free and artifact-free periods lasting at least 5 minutes were selected around each of these SUD moments. All physiological reactivity scores were computed based on these 5-minute periods to ensure the temporal overlap of the subjective and physiological measurements of fear activation.

Thirty minutes after disembarking, participants filled out the VAFAS questionnaire assessing the short-term outcome of treatment regarding flight anxiety. Three years later, long-term follow-up effects of treatment were collected by email. Next to a self-report of flight anxiety (VAFAS) participants furnished the number of flights flown within the three years since end of therapy to provide a behavioural indication of treatment success.

Data analysis

Three separate conditions with increasingly realistic stimuli were used. In the first condition participants twice viewed an anxiety inducing flight video, each time preceded by a neutral video. In the second condition participants were exposed to more realistic stimuli with higher intensity during two simulated flights. The third most ecologically valid condition with highest intensity stimuli utilised two in-vivo flights. Fear reactivity to the flight video was defined as the change in the SUD variable and the three physiological variables (HR, RSA, and PEP) from the neutral and flight videos. Fear reactivity to the simulated and real flights was defined as the changes in the SUD and physiological variables during exposure, compared to a neutral baseline reflecting the entire morning (excluding flight video) of the first day of CBGT.

Pairwise t-tests and Cohen's d were calculated to assess whether there were significant changes in reactivity across repeated exposures in all three conditions. To test the first hypothesis that synchronous change between subjective and physiological reactivity increased with intensity and ecological validity of emotional stimuli, changes in the reactivity of subjective distress and of the three physiological variables across repeated exposures were computed for all three conditions. For the video stimuli, we subtracted reactivity to the second video presentation from reactivity to the first video presentation. Likewise, for the simulator we subtracted reactivity to the second simulated flight from reactivity to the first simulated flight. For the actual flight we subtracted reactivity to the end of the second flight from reactivity to the start of the first flight. This subtraction resulted in change scores that reflect the change in subjective and physiological reactivity over repeated exposures. These change scores were used to assess the magnitude of synchronous change as the Pearson correlation coefficients between the change score for subjective distress and the change score for each of the physiological variables. Significance of the increase in these correlations with increased intensity and ecological validity was tested by the method developed by Zou (2007).

Multiple hierarchical regression analyses were used to test the second hypothesis that a higher amount of synchronous change is associated with better treatment outcome. Separate analyses were performed for video-, simulator- and flight-exposure. Predictor variables were the SUD, HR, RSA and PEP changes from first- to second- exposure. The products of the SUD change scores with the physiological change scores were added to the regression models in the second step of the regression analyses. Significance of a two-way interaction in this second step of the regression model would be an indication that synchronous change was related to treatment outcome (Benoit Allen et al., 2015). For example, a significant interaction between changes in SUD and changes in HR would indicate that synchrony between these two components was associated with treatment outcome. Short-term outcome was operationalized as the flight anxiety score taken directly after the second exposure flight. Long-term outcome was operationalized as the flight anxiety score three years after treatment, and number of flights taken in this three-year period. To compensate for individual baseline differences in the flight anxiety outcome variables these anxiety scores were regressed on the flight anxiety score taken during diagnostic assessment. After analyses of the relationship between age and gender with all variables of interest we concluded that it was not necessary to control for both variables in further analyses. Throughout all regression analyses we first computed saved standardized residuals by regression of second exposure reactivity scores on first exposure reactivity scores, and subsequently used them as independent variables in the final regression analyses. This way it was not necessary to control for baseline values in an additional first step in the hierarchical regression analysis; this procedure reduced the number of predictor variables while reaching similar results.

The security checks at the airports turned out to be a major challenge for the physiological measurements. The attached electrodes of the ambulatory measurement device required a physical patting down of all participants. Consequently, data on one or more physiological variables during flight were lost for 15 participants. Data of two participants were lost due to equipment failure during flight. One flight was cancelled due to adverse weather, resulting in the loss of flight data of two participants. All available data were used for analysis without excluding participants, as data loss was completely random. Missing data were not replaced or substituted. RSA and Number of Flights Flown within three years of end of therapy were log (Ln) transformed to obtain normal distributions.

RESULTS

Table 1 shows subjective and physiological reactivity across repeated exposures in the three conditions. As expected, participants showed marked subjective fear responses and minimal physiological reactivity to the low intensity artificial video stimuli. Physiological reactivity increased progressively from video to simulator to real flight exposure, but less so for the second than the first exposure, resulting in marked changes across repeated measurements in the flight condition. Subjective reactivity showed progressively larger changes across repeated measurements from video to simulator to real flight exposure. Pearson correlation coefficients were computed as an indication of synchrony in the changes in subjective and physiological reactivity. Only weak evidence for synchrony was found and, contrary to our first hypothesis, in the most intense and ecologically valid condition none of these correlations proved to be significant[1] (table 2).

Multiple hierarchical regression analyses were performed to test the second hypothesis that participants with more synchronous change in the two response systems during treatment would show better short-term and long-term treatment outcomes than would participants with less synchronous change during treatment. Changes in subjective (SUD) and physiological (HR, RSA, PEP) reactivity were added in the first step of the regression analyses. In a second step all two-way interactions (SUD/HR, SUD/RSA and SUD/PEP) were added. This was the critical test of our second hypothesis, where significance of a two-way interaction would be an indication that more synchronous change would predict better treatment outcome. Contrary to this hypothesis, the results revealed no significant interaction effect in any condition for none of the three paired variables (SUD/HR, SUD/RSA and SUD/PEP).

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[1] Simple change scores were used to facilitate interpretation of changes in reactivity across repeated exposures. For consistency, Pearson correlation coefficients were computed based on these simple change scores. We also reran the analyses computing saved standardized residuals by regressing second exposure reactivity scores on first exposure reactivity scores, and subsequently used them in further analyses. This led to highly similar results.

Table 1. Reactivity of SUD, HR, RSA and PEP to First and Second exposure to the phobic stimuli in the three conditions and the Change in reactivity across repeated exposure.

Condition	First	Second	Change	t	p	Cohen's d
Video						
SUD	1.36 (1.6)	.87 (1.3)	.49 (1.4)	2.99	.004	.34
HR	-.179 (3.2)	.104 (2.5)	-.28 (3.6)	-.67	.503	.10
RSA (ms)	-2.82 (15.3)	-.12 (10.0)	-2.70 (16.7)	-1.28	.204	.19
PEP (ms)	.32 (3.3)	.24 (3.7)	.081 (4.8)	.145	.885	.02
Simulator						
SUD	1.77 (1.8)	.38 (1.3)	1.39 (1.4)	7.025	< .001	.89
HR	14.4 (8.9)	14.3 (7.2)	.27 (6.1)	.358	.722	.01
RSA (ms)	-11.4 (18.1)	-9.57 (19.1)	-1.83 (9.5)	-3.25	.002	.28
PEP (ms)	-11.5 (21.6)	-11.2 (22.6)	-.29 (5.5)	-.434	.665	.02
Flight						
SUD	1.57 (2.0)	-.80 (1.6)	2.36 (1.8)	10.7	< .001	1.31
HR	25.7 (11.2)	12.7 (9.6)	13.0 (8.1)	11.7	< .001	1.25
RSA (ms)	-18.3 (17.5)	-13.0 (16.6)	-5.25 (12.9)	-3.14	.003	.40
PEP (ms)	-13.2 (21.6)	-8.84 (22.7)	-4.38 (8.85)	-3.6	.001	.20

SUD = Subjective Units of Distress, HR = Heart Rate,
RSA = Respiratory Sinus Arrhythmia, PEP = Pre-Ejection Period.

Table 2. Correlation coefficients of changes in subjective reactivity with changes in physiological reactivity across repeated exposure in the three conditions.

	SUD with	HR	RSA	PEP
Condition				
Video		.303 **	.031	-.166
Simulator		.189	-.301 *	-.053
Flight		-.035	-.074	.098

* significant at .05 ** significant at .001.

Main effects for changes in SUD and HR emerged during the flight exposure, and a main effect for changes in HR emerged during the simulator exposure, both for short-term outcome. Participants with less diminution in HR over simulated flights reported less decrease in flight anxiety from beginning to end of therapy than participants with more diminution of HR over the simulated flights. Participants who reported less decrease in distress over real flights reported less decrease in flight anxiety from beginning to end of therapy than participants who reported a larger decrease in distress over real flights, and participants with less diminution in HR over real flights reported less decrease in flight anxiety from beginning to end of therapy than participants with more diminution of HR over both real flights (results partly published in Busscher, Spinhoven, van Gerwen,

Table 3. Regression analyses of short-term treatment outcome on changes over flights in subjective distress (SUD) and changes over flights in physiological measures (HR, RSA and PEP) and their interaction.

	VAFAS Short-term				
	B	**SE**	**t**	**p**	**Zero-order correlations**
Step 1					
Constant	.10	.144	.070	.944	-
SUD changes	.423	.157	2.699	.011	.303
HR changes	.476	.169	2.813	.008	.309
RSA changes	.252	.153	1.646	.108	-.035
PEP changes	.059	.158	.375	.710	-.074
Step 2					
Constant	-.074	.158	-.469	.642	-
SUD changes	.571	.220	2.597	.014	.303
HR changes	.422	.171	2.460	.019	.309
RSA changes	.252	.163	1.546	.132	-.035
PEP changes	-.006	.170	-.033	.974	-.074
Interaction SUD-HR	-.361	.203	-1.777	.085	-.162
Interaction SUD-RSA	-.083	.173	-.482	.633	-.029
Interaction SUD-PEP	.004	.213	.017	.987	-.164

VAFAS = Visual Analogue Flight Anxiety, SUD = Subjective Units of Distress, HR = Heart Rate, RSA = Respiratory Sinus Arrhythmia, PEP = Pre-Ejection Period.

& de Geus, 2013). Table 3 illustrates the regression model for the flight condition with the short-term effect on flight anxiety as the dependent treatment outcome variable. Detailed results of all outcomes in all conditions (video-exposure, simulator-exposure and flight-exposure) are provided in the supplemental materials section.

DISCUSSION

For more than 130 years (James, 1884) emotion has been conceptualised as the organising entity that coordinates response systems to aid survival. Response coherence is expected to mirror this process, even more so during demanding circumstances (Hollenstein & Lanteigne, 2014). Evidence for concordance in the reactivity of the response systems and synchronous change in their reactivity over time has been sparse (Alpers, 2008; Beckham et al., 1990; Ekeberg et al., 1990; Nesse et al., 1985). This was hypothesized to have been caused by the generally low intensity of the stimuli used in the published research (Hollenstein & Lanteigne, 2014; Levenson, 2014a). Therefore, in the present study we followed highly aviophobic participants who were exposed to increasingly realistic and ecologically valid stimuli, including two actual flights. Participants showed marked subjective and physiological reactivity, and marked changes across repeated exposures, especially in the actual flight condition. Nevertheless, at group level, these intense and ecologically very valid stimuli did not evoke synchronous change in self-reported and physiological reactivity. So far, little proof has been provided that synchronous change is coupled to intensity of stimuli and emotional functioning (Hollenstein & Lanteigne, 2014; Levenson, 2014a). Individual reactivity in each of the two response systems was coupled to treatment outcome. However, synchronous change in the two systems was not indicative of short-term and long-term treatment results. Results in the present study are therefore not in line with the assumption of Hodgson and Rachman (1974) that successful treatment of anxiety disorders should be indicated by synchronous change.

Results from empirical studies often add complexity to an attractive theoretical perspective. Of course, the model could be wrong. It is conceivable that research on coherence is subject to the file-drawer phenomenon and that many null findings have not been published. Nevertheless, null findings are not refutations. Maybe the coordinating role of emotion is not at all mirrored by response coherence. On the other hand, other processes might conceal this relationship. Emotion regulation is a complex process that includes conscious and unconscious physiological, behavioural and cognitive processes that modulate emotions to respond appropriately to environmental demands (Aldao, Nolen-Hoeksema, & Schweizer, 2010; Gross, 2001; Thompson, 1991; Thompson, 1994). Cognitive coping strategies like self-blame, rumination, catastrophizing and avoidance play a prominent role within the anxiety pathologies (Garnefski et al., 2002; Martin & Dahlen, 2005). For example, cognitive avoidance, the conscious suppression of unwanted thoughts, could counterproductively lead to increased accessibility of the suppressed thoughts and hence result in hypersensitivity to anxiety-related thoughts and symptoms (Wegner & Zanakos, 1994; Wenzlaff & Wegner, 2000). Cognitive coping strategies could mediate the relationship between self-report of anxiety and the psychophysiological components of anxiety. We judge and feel emotions about our emotions. Perceiving an emotion as unacceptable, problematic, or aversive, instead of normal, can influence the way a person regulates the emotional state itself (Couyoumdjian et al., 2016; Schaefer, Larson, Davidson, & Coan, 2014). Couyoumdjian et al. (2016) report preliminary evidence that a reduction in negative self-evaluation contributed to a decrease of autonomic arousal in reaction to a phobic stimulus. Sixteen animal phobic participants, who received a short cognitive treatment to reduce dysfunctional thoughts about the self, showed a reduced physiological arousal (decreased HR and increased HRV) but no change in subjective symptoms during and shortly after exposure to an individualized phobic video clip. The seventeen phobic control participants who did not receive treatment showed no change in physiological and subjective symptoms of anxiety during and after phobic exposure.

Phobic provocation is an intensely fearful experience. A conflict between uncontrollable, automatic phobic reaction and the recognition that the phobic fear response is irrational and even embarrassing may lead to an increased attempt at emotion regulation, in an effort to suppress or control the fear reaction (Schaefer et al., 2014). The effect of cognitive behavioural therapy might partly be explained by additional cognitive regulation strategies being brought online to dampen automatic and coherent responses. The time course of emotion subsystems may vary greatly (Hollenstein & Lanteigne, 2014; Levenson, 2014b), and may vary even more owing to this additional cognitive regulation. Cross-correlation concordance analyses with short time-windows (-10 seconds to + 10 seconds) have been used to compensate for the different temporal characteristics of response systems (Butler, Gross, & Barnard, 2014; Dan-Glauser & Gross, 2013; Mauss, Levenson, McCarter, Wilhelm, & Gross, 2005; Sze, Gyurak, Yuan, & Levenson, 2010). However, as far as we know no lagged cross-correlation analyses on synchronous change have been published. In the present study we used 5-minute time windows around each of the SUD moments for the physiological measures during the flight condition, thereby effectively compensating for short-term temporal deviations.

Strengths, limitations and future directions

As in many studies on coherence, participants retrospectively reported SUDs immediately after the video presentations and both simulated flights, whereas ANS responses were acquired during the phobic induction itself. Ideally, coherence should be examined with simultaneous acquisition of ANS and experiential variables (Hollenstein & Lanteigne, 2014; Levenson, 2014b). During the actual flight physiological- and SUD-measurements had a perfect temporal overlap, preventing retrospective memory biases. The present study used a straightforward definition of synchronous change combined with an unambiguous operationalization of fear intensity. Individual subjective and physiological baseline differences were effectively compensated (Hollenstein & Lanteigne, 2014; Levenson, 2014b). Another positive point was the use of two entirely different clinically relevant long-term outcome measures: a behavioural measure indicating flight behaviour and a self-report measure indicating flight anxiety. However, subjective reactivity during the phobic inductions was assessed by one single questionnaire only. Furthermore, the behavioural component of the tripartite model was not tested.

Fear is invoked in situations where action is required (van Duinen, Schruers, & Griez, 2010). A primary function is to redirect energy resources to prepare the body for flight or fight. This surplus of available energy is of no use once one is inside an airplane because overt behaviour is severely restricted in this situation. The discrepancy between action-readiness and the inability to execute physical motion is very clear in this example, but actually applies to all the research on concordance. Only Vermilyea et al. (1984) had agoraphobic patients actually walk during assessment, and reported treatment responders to have synchronous changes as often as desynchronous changes. The influence of suppression of overt behaviour on synchronous changes in subjective reports of distress and physiological measures of arousal warrants further study.

Another positive point of the present study is the use of multiple measures of ANS reactivity as recommended by Hollenstein and Lanteigne (2014). HR is the most commonly used physiological measure in coherence research (Levenson, 2014b). HR is a sensitive measure that captures phobic fear intensity at both extremes of the fear continuum (Aue, Hoeppli, & Piguet, 2012; Kreibig, 2010; Wilhelm & Grossman, 2010). Furthermore, it has high face validity. However, HR changes are foremost caused by bodily needs to restore homeostasis. Emotion is just one of many influences on the ANS. The heart is dually innervated: at rest, HR is under parasympathetic restraint slowing the intrinsic pacemaker cells from approximately 100 beats per minute to a mere 70 beats per minute. Increased sympathetic activity, but also reduced parasympathetic activity, will increase HR. For example, Hu, Lamers, de Geus, and Penninx (2016) report in a large group of people with depressive and anxiety disorders that increased ANS stress reactivity to an ecologically valid stressor was probably caused by vagal withdrawal. HR alone does not indicate which branch of the autonomic system influences the heart. RSA and PEP, as also used in the present study, are more informative. Alternative non-intrusive reliable and sensitive measures to capture ANS activity in an ambulatory setting are few. For example, electrodermal activity is susceptible to movement artifacts, pupil dilation measurement is hardly feasible under naturalistic conditions, and endocrine measures via saliva collection may alter behaviour (Alpers, W., 2009; Kreibig, 2010; Wilhelm & Grossman, 2010). Nevertheless, future research could benefit from moving beyond cardiac measures (Levenson, 2014a).

Response coherence has been difficult to capture, and poses a number of methodological and data-analytic challenges (Bulteel et al., 2014). Most research on coherence used a between-subjects rather than a within-subjects approach (Levenson, 2014b). To find synchronous change in reactivity across response systems, studies need to assess and correlate this reactivity within the same individual (Hollenstein & Lanteigne, 2014; Levenson, 2014b). Here we used such a within-subject design, following a previous study by Benoit Allen et al. (2015), to test the hypothesis that increased synchronous change is coupled with better treatment results. The possible delayed effect of emotion regulation on the tripartite components requires new longitudinal analytic approaches to statistically model the process of synchronous change of multiple response systems with different temporal characteristics.

Clinical implications

The aim of cognitive behavioural therapies is to "*help individuals to optimize their adaptation to circumstances that arise in their lives*" (Mennin, Ellard, Fresco, & Gross, 2013, p. 236) by fostering flexibility and promoting behavioural adaptation. It has been thought that the magnitude of coherence could be an indication of progress during therapy; however, the relationship between domains is not straightforward and is possibly affected by many intervening processes and variables. Higher order cognitive processes seem to intervene with the supposititious temporal associations between responses (Mauss et al., 2005; Schaefer et al., 2014). If an effect of cognitive therapy is a reduction of automatic and coherent responses between domains, then this might lead to a lagged or reduced physiological fear response (Schaefer et al., 2014). Blunted physiological fear responses might diminish effectiveness of (in-vivo) exposure therapy, as according to the emotional processing theory (EPT) (Foa & Kozak, 1986), fear activation is a prerequisite for fear-extinction. Cognitive interventions, aimed at alleviating fear or at promoting regulating strategies that dampen automatic and coherent responses, might better be postponed to after the exposure component of the treatment (Busscher, Spinhoven, & de Geus, 2015; Craske, Treanor, Conway, Zbozinek, & Vervliet, 2014). Furthermore, treatment programs would do best not to focus too much on concordant changes in self-reported and physiological indicators of arousal.

CONCLUSION

Results in the present study did not show a relationship between the intensity of the phobic stimuli and the magnitude of synchronous change in subjective and physiological reactivity. Furthermore, even with exposure to ecologically valid stimuli of high phobic intensity, we did not find evidence that a higher magnitude of synchronous change is coupled to a more favourable treatment outcome. For the time being, the functionalistic view that successful treatment of anxiety disorders is indicated by synchronous change between the tripartite domains remains a hypothesis with high face validity, but a very poor empirical basis.

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SUPPLEMENTAL MATERIAL