Consciousness and Cognition 21 (2012) 1401–1409

Contents lists available at SciVerse ScienceDirect

Consciousness and Cognition

journal homepage: www.elsevier.com/locate/concog

Obsessive–compulsive tendencies may be associated with attenuated access to internal states: Evidence from a biofeedback-aided muscle tensing task

Amit Lazarov, Reuven Dar *, Nira Liberman, Yuval Oded

Tel Aviv University, Israel

A R T I C L E   I N F O

Article history:
Received 23 March 2012
Available online 28 July 2012

Keywords:
Obsessive–compulsive disorder
Doubt
Checking
Biofeedback

A B S T R A C T

The present study was motivated by the hypothesis that inputs from internal states in obsessive–compulsive (OC) individuals are attenuated, which could be one source of the pervasive doubting and checking in OCD. Participants who were high or low in OC tendencies were asked to produce specific levels of muscle tension with and without biofeedback, and their accuracy in producing the required muscle tension levels was assessed. As predicted, high OC participants performed more poorly than low OC participants on this task when biofeedback was not available. When biofeedback was provided, the difference between the groups was eliminated, and withdrawing the monitor again reversed this effect. Finally, when given the opportunity, high OC participants were more likely than low OC participants to request biofeedback. These results suggest that doubt in OCD may be grounded in a real and general deficiency in accessing internal states.

1. Introduction

One of the principal symptoms in patients with obsessive–compulsive disorder (OCD) is persistent doubt that can invade many domains of actions and feelings and lead to a variety of pathological behaviors typical of OCD, including excessive self-monitoring, repeated checking, mental reconstruction, repeated questions and demands for external validation or reassurance (American Psychiatric Association, 2000; Dar, 2004). The role of this endemic doubt and uncertainty in the phenomenology and etiology of OCD has been widely acknowledged in research and in theoretical models of the disorder. Excessive doubt in OCD has been demonstrated in relation to various cognitive functions such as memory (e.g., Constans, Foa, Franklin, & Mathews, 1995; Cougle, Salkovskis, & Wahl, 2007; McNally & Kohlbeck, 1993; Sher, Frost, & Otto, 1983; Tolin et al., 2001), decision making and concentration (Nedeljkovic & Kyrios, 2007; Nedeljkovic, Moulding, Kyrios, & Doron, 2009), attention and perception (Hermans, Martens, De Cort, Pieters, & Eelen, 2003; Hermans et al., 2008; van den Hout, Engelhard, de Boer, du Bois, & Dek, 2008; van den Hout et al., 2009) and personal knowledge (Dar, Rish, Hermesh, Fux, & Taub, 2000). Classic models of OCD contended that OCD patients also doubt other internal states, such as feelings, preferences, comprehension, wishes and beliefs (Janet, 1903; Rapoport, 1989; Reed, 1985; Shapiro, 1965). Finally, more recent models of OCD have postulated a central role for doubt and uncertainty in regard to concerns about safety (Boyer & Lienard, 2006; Szechtman & Woody, 2004), task completion (Summerfeldt, 2004, 2007) and the self-concept (e.g., Aardema & O'Connor, 2007; Doron, Kyrios, & Moulding, 2007).

In line with the research and models mentioned above, we have recently hypothesized that obsessive–compulsive (OC) individuals have a reduced sense of subjective conviction. We suggested that this reduced conviction is not limited to

* Corresponding author. Address: School of Psychological Sciences, Tel Aviv University, Tel Aviv 69978, Israel. Fax: +972 3 6409547.
E-mail address: ruvidar@freud.tau.ac.il (R. Dar).

1053-8100/$ - see front matter
http://dx.doi.org/10.1016/j.concog.2012.07.002

harm-avoidance or task-completion concerns, but can be relevant to any internal state. By internal states we mean subjective states that cannot be fully assessed by outside observers or objective measures. Internal states can be cognitive (e.g., perception, memory, comprehension), affective (e.g., attraction, specific emotions) or bodily (e.g., muscle tension, proprioception). In addition, we suggested that OC individuals attempt to compensate for their deficient subjective conviction regarding these internal states by developing and relying on proxies for subjective experiences. By "proxies" we mean substitutes for the internal state that the individual perceives as more easily discernible or less ambiguous, such as rules, procedures, behaviors or environmental stimuli (Liberman & Dar, 2009). We termed this hypothesis Seeking Proxies for Internal States (SPIS; Lazarov, Dar, Liberman, & Oded, 2011; Lazarov, Dar, Oded, & Liberman, 2010). In terms of the SPIS hypothesis, compulsive rituals are seen as attempts to develop and rely on proxies as a compensation strategy against a reduced sense of certainty or subjective conviction regarding internal states. For example, learning school material by heart and reciting it three times can be adopted as a means of compensating for loss of conviction in regard to whether one has fully understood the material. In terms of the SPIS hypothesis, such procedures would be conceptualized as proxies for understanding.

The need for individuals with OCD to seek indicators or cues for internal states has been postulated in previous theoretical accounts of OCD. Wahl, Salkovskis, and Cotter (2008) have suggested that due to the operation of Elevated Evidence Requirements (EERs) in areas of inflated responsibility, OCD individuals use potentially counter-productive "stop criteria," seeking to achieve a particular "feeling of rightness" based on both external and internal cues. According to the EER model, individuals with OCD doubt whether it is "safe" to terminate an action until enough evidence – subjective internal feelings as well as objective sensory input – has been acquired. Although similar in several aspects, the SPIS hypothesis differs from the EER model in several ways. According to the SPIS hypothesis, individuals with OCD rely on proxies and use them not only as evidence for the appropriateness of stopping a compulsive act, but also more generally as relatively discernible or less ambiguous substitutes for internal states. Furthermore, we propose that this compensatory strategy can be manifested in any domain where doubt and uncertainty can emerge and is not limited to areas of inflated responsibility (although it is plausible that SPIS might be enhanced in situations that trigger responsibility or other OC-relevant concerns).

A recent series of studies using biofeedback procedures have provided preliminary support for the SPIS hypothesis. Lazarov et al. (2010) asked participants to relax deeply while being connected to a biofeedback monitor, which recorded their galvanic skin response (GSR) fluctuations, an established physiological index of relaxation. As predicted, high OC participants performed worse than low OC participants on this relaxation task. More importantly, when a proxy for relaxation was provided in the form of the biofeedback monitor, it improved the ability to relax among high OC participants but not among low OC participants. Finally, when given the opportunity, high OC participants were more likely than low OC participants to request biofeedback in trying to achieve a state of relaxation. In another study, Lazarov et al. (2010) found that high OC participants, compared to low OC participants, were more influenced by false biofeedback in judging their own level of relaxation, indicating that they were less certain about this internal state. Similar results emerged when participants were asked to relax their muscles, and muscle tension (EMG) was measured instead of GSR (Lazarov et al., 2011).

The studies by Lazarov et al. (2010, 2011) demonstrate that OC tendencies are associated with a reduced sense of one's own level of relaxation, as well as with an increased tendency to seek and to rely on objective proxies for these states. These studies, however, leave two open questions, both of which we attempt to address in the present report. First, it is unclear whether these findings are specific to relaxation. Possibly, because OC tendencies are related to anxiety, they are also associated with inability to relax and perhaps with deficient access to one's state of relaxation. We therefore tested our hypothesis in this study with a task that is not confounded with relaxation ability. Specifically, we used a magnitude-production task (see Procedure below), previously used in electromyography biofeedback studies to test muscle-tension awareness and control ability, which are distinct from decreasing muscle tension (Bayles & Cleary, 1986; Glaros & Hanson, 1990; Segreto, 1995; Stilson, Matus, & Ball, 1980). This procedure requires participants to achieve specific levels of muscle tension rather than to relax their muscles, and therefore would not be expected to correlate with anxiety.

The second question that our previous results left open is whether participants high in OC tendencies had deficient access to their state of relaxation, or rather had intact access but doubted their assessment of this internal state. In the second scenario, the doubts and the self-questioning they produced may have disrupted the ability of high OC participants to relax. The first possibility is consistent with recent models that postulate a real deficiency in internal signals, cues or feelings in OCD, a deficiency that leads to repetitious behaviors and compulsions (e.g., Boyer & Lienard, 2006; Summerfeldt, 2004, 2007; Szechtman & Woody, 2004). This possibility is also consistent with memory studies showing real deficits in memory abilities among OCD patients (e.g., Abramovitch, Dar, Schweiger, & Hermesh, 2011; Boone, Ananth, Philpott, Kaur, & Djenderjian, 1991; Christensen, Kim, Dyksen, & Hoover, 1992; Savage et al., 2000; Sher et al., 1983; Tallis, Pratt, & Jamani, 1999; Tuna, Tekcan, & Topçuoğlu, 2005; Woods, Vevea, Chambless, & Bayen, 2002; Zitterl et al., 2001) and with experimental evidence of a dysfunctional biological-somatic marker in OCD participants, affecting decision-making processes (Cavedini et al., 2012; Stracke, Tuschen-Caffier, Markowitsch, & Brand, 2009). The second possibility is consistent with studies showing that excessive checking, whether behavioral (Ashbaugh & Radomsky, 2007; van den Hout & Kindt, 2003a, 2003b; van den Hout et al., 2008, 2009; Radomsky, Gilchrist, & Dussault, 2006; Tolin et al., 2001) or mental (Radomsky & Alcolado, 2010), can lead to increased distrust of one's own memory and perception. It is also consistent with studies that found no real memory deficits in OC individuals other than memory confidence (e.g., Abbruzzese, Bellodi, Ferri, & Scarone, 1993; Ceschi, Van der Linden, Dunker, Perroud, & Bredart, 2003; Foa, Amir, Gershuny, Molnar, & Kozak, 1997; Jelinek, Moritz, Heeren, & Naber, 2006; Karadag, Oguzhanoglu, Ozdel, Atesci, & Amuk, 2005; Kim et al., 2006; Simpson et al., 2006).

The present study was designed as a first attempt to distinguish between these two possible sources of doubt. For that purpose we designed a task in which performance would reflect access to internal states and could not be attributed solely to the operation of obsessions or doubts. The magnitude-production task measures accuracy in producing designated levels of muscle tone. Accurate performance in this task depends on correct assessment of one's own level of muscle tension, so if OC individuals have attenuated access to their internal states, they should be less accurate in producing the required levels of muscle tension.

We have shown in previous studies, using various tasks, that in contrast to speed and efficiency, accuracy is typically not affected by OC doubts and self-questioning. For example, Dar et al. (2000) found that OC checkers showed reduced confidence in their general knowledge compared with panic-disorder patients and non-patient controls, but their accuracy was intact. Sarig, Dar, and Liberman (2012) found that OC tendencies were related to indecisiveness, but not to accuracy, in a neutral color judgment task. Soref, Dar, Argov, and Meiran (2008) found that OC tendencies were related to focused information processing strategy, but not to accuracy, in the flanker task. Accordingly, doubts and self-questioning were not expected to interfere with accuracy in producing muscle tension and would therefore not constitute probable alternative accounts of less accurate performance on the part of high OC participants.

As in our previous studies, the present study employed a sample of extreme high and low scorers on a measure of OCD. Based on the reasoning explained above, we predicted that in the absence of biofeedback, the high OC participants, as compared with the low OC group, would perform more poorly on the magnitude-production task, which relies on subjective internal cues. We also predicted that viewing the biofeedback monitor would improve the performance of the high OC participants more than that of the low OC participants. Finally, we predicted that when given the opportunity, the high OC participants will be more inclined than the low OC participants to seek the biofeedback monitor.

2. Method

2.1. Participants

Two hundred and one psychology students (152 women, 49 men) at Tel-Aviv University were screened with the Obsessive–Compulsive Inventory-Revised (OCI-R; Foa et al., 2002; see Section 2.3 below). We invited students who scored at the top and bottom of the distribution for participation in this study, with a cutoff score of 31 for high OC participants and a cutoff score of 5 for low OC participants. The final sample included 36 students (*M* age = 22.64 years, *SD* = 1.9, range = 20–29 years): Eighteen (15 women and 3 men) with high OC tendencies (*M* = 37.61, *SD* = 6.66) and 18 (13 women and 5 men) with low OC tendencies (*M* = 2.39, *SD* = 1.85), $t(34) = 21.61$, $p < .001$. The scores in the high OC group ranged between 23 and 58, and in the low OC group between 0 and 5. For comparison, the mean OCI-R for OCD patients in Foa et al. (2002) was 28.01 (*SD* = 13.53) with a cutoff score of 21 for differentiating OCD patients from non-anxious controls, and 18 for differentiation from anxious controls. In a previous study in our laboratory (Reuven-Magril, Dar, & Liberman, 2008) the mean OCI-R for OCD patients was 29.22 (*SD* = 15.22). The two groups differed significantly ($p < .001$) on all the subscales of the OCI-R. None of the participants had prior experience with biofeedback. Participants signed an informed consent and received course credit for participation.

2.2. Apparatus

Physiological data regarding muscle activity was measured using the Procomp Infiniti hardware and Biograph Infinity software from Thought Technologies, Montreal, Canada. This biofeedback apparatus, as well as other versions of it, were shown in previous studies to provide a reliable measure of muscle activity in a wide range of clinical contexts and at different muscle sites (e.g., Bravo, Coffin, & Murphey, 2005; Jantos, 2008; Mandryk & Atkins, 2007; Mandryk, Inkpen, & Calvert, 2006; Noe, Amarantini, & Paillard, 2009; Reissing, Binik, Khalife, Cohen, & Amsel, 2004). For each participant, a single triode electrode was applied on the skin over the flexor carpi ulnaris muscle (i.e. the muscle that contracts in the forearm when making a fist) of the participant's dominant arm. The electrode was connected to a sensor and the data were transmitted to a laptop computer via a biofeedback encoder. The sensor measured electromyography (EMG) – electrical signals generated during muscle activity (Peek, 2003). EMG changes were reflected on the computer screen as an upward-downward movement of a horizontal line along a vertical numerical axis ranging from 0 at the bottom to 5 at the top, with intervals of one. Each of the six values corresponded to a different EMG reading in microvolt: 0 equaled 0 μv, 1 equaled 4 μv, 2 equaled 8 μv, 3 equaled 12 μv, 4 equaled 16 μv and 5 equaled 20 μv. An upward movement of the line signaled an increase in muscle tension, whereas a downward movement of the line signaled a decrease in muscle tension.

2.3. Measures

2.3.1. Obsessive–compulsive tendencies

Obsessive compulsive tendencies were measured by the Obsessive–Compulsive Inventory-Revised (OCI-R; Foa et al., 2002). The OCI-R lists 18 characteristic symptoms of OCD. Each symptom is followed by a 4-point Likert scale ranging from 0 (*not at all*) to 4 (*extremely*), on which participants indicate the symptom's prevalence during the last month. The OCI-R has been shown to have good validity, test–retest reliability and internal consistency in both clinical (Foa et al., 2002) and non-clinical samples (Hajack, Huppert, Simons, & Foa, 2004). Cronbach's alpha of the OCI-R in our sample was .88, which is identical to the figure reported in previous studies with college samples (Hajack et al., 2004; Lazarov et al., 2010, 2011; Soref et al., 2008).

2.3.2. Muscle tension

Muscle tension was measured by averaging the EMG readings (in μv) of each participant during each experimental trial, such that a high score indicated higher muscle-tension and a low score indicated lower muscle-tension. EMG measures muscle activity by detecting surface voltage that occurs when a muscle is being contracted, which constitutes the EMG signal (Peek, 2003). EMG has been widely used in previous clinical and experimental studies as a reliable and valid measure of muscle activity or tension. Some studies have utilized EMG as a measure to help individuals decrease muscle tension (e.g., Ince, Leon, & Christidis, 1987; McGrady & Linden, 2003; Neblett, Gatchel, & Mayer, 2003; Schwartz & Adrasik, 2003; Schwartz & Sedlacek, 2003), others for training individuals to increase muscle tension (e.g., Cohen, Richardson, Klebez, Febbo, & Tucker, 2001; Croce, 1986; Fogel, 2003; Ince et al., 1987; Krebs & Fagerson, 2003; Middaugh & Miller, 1980; Moreland, Thomson, & Fuoco, 1998) and more relevant to the present study, some have utilized EMG as a measure to help individuals increase muscle control and awareness (Bayles & Cleary, 1986; Glaros & Hanson, 1990; Kinsman, O'Brien, Robinson, & Staudenmater, 1975; Lehrer, Batey, Woolfolk, Remde, & Garlick, 1988; Segreto, 1995; Sime & DeGood, 1977; Staudenmayer & Kinsman, 1976; Stilson et al., 1980).

2.4. Procedure

Participants were tested individually in a small and quiet room. Upon arriving, the experimenter attached the electrode to the forearm of the participant's dominant arm. Participants were instructed to sit comfortably and refrain from talking or moving as much as possible while viewing a landscape presentation on the computer for 11 min. This period served as an adaptation period, and resting baseline EMG was recorded during the last 3 min. Next, participants were told that during the experiment they will be asked to produce four target levels of forearm muscle tension that ranged from 1 to 4, with 1 being lower and 4 being higher. The experimenter then guided the participant to produce two anchor tension levels, specifically the level that was labeled 1 (4 μv) and the level that was labeled 4 (16 μv). These anchors were attained by instructing participants to contract their forearm muscle until they achieved the designated response, at which point they were told "OK, this level is a one/four". During this anchoring process participants did not receive any other feedback. The experiment did not resume until participants were able to produce each of the two anchor levels twice. There was a 2-min break before proceeding to the first experimental phase.

During the first phase participants were asked to produce different muscle tension levels, ranging from 1 to 4, and to hold it at that level until they were told to stop. Trials were 5-s long, with a 15-s rest period between trials in order to reduce fatigue. The different levels were presented in pseudo-random order, with the same order of presentation for all participants and across phases. The first phase consisted of 12 trials, during which participants were unable to view the biofeedback monitor.

After the first phase participants received a brief explanation as to the general nature and function of the biofeedback apparatus. This explanation was followed by a 2-min "self discovery" period during which participants were able to familiarize themselves with the apparatus, with no specific instructions. Phases two and three replicated phase one, again instructing participants to produce different muscle tension levels ranging from one to four, first while viewing the biofeedback monitor (second phase) and then again without viewing the monitor (third phase).

Before the fourth and final phase participants were told that at several trials during this phase the experimenter will offer them a chance to view the biofeedback monitor for a few seconds each time, so that they will be able to see their progress and current state, but that it might impair their performance. Participants were offered the choice of whether or not to view the monitor at six trials during this phase (during trials 2, 4, 6, 8, 10 and 12). At those trials the experimenter asked "Would you like to see the monitor?" and participants were to nod if they chose to view the monitor and to withhold response if they chose not to. When choosing to view the monitor the experimenter rotated the biofeedback monitor toward the participant and then turned it back again. Each of the first three phases was followed by a 5-min interval of watching a screen saver on the monitor, in order to permit the participant's muscle tension to return to its baseline level before proceeding to the next phase, as well as to reduce fatigue effects as much as possible.

During the first three phases, we measured the average EMG as defined above. For each participant we derived a deviation score for each trial by computing the absolute difference between the target and the actual physiological response in that particular trial. We then averaged the deviation scores across trials for each phase. During the fourth and final phase we counted the number of times each participant requested to view the biofeedback monitor.

3. Results

A two-tail independent sample *t*-test on baseline EMG level indicated that there were no significant differences between the two groups, $t(34) = 1.29$, $p = .20$. Fig. 1 displays the deviation score of the two groups in the three phases of the

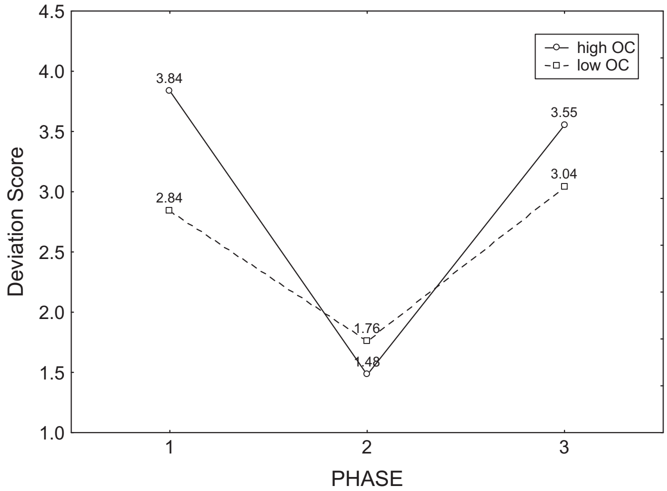

Fig. 1. Mean absolute deviations from target muscle tension by phase and OC tendencies.

experiment. We tested our hypotheses within a 2 (OC tendencies: high vs. low) × 3 (phase: P1–P3) mixed-model analysis of variance (ANOVA) with deviation score as the dependent measure. As predicted, the high OC group had a significantly higher mean deviation score than the low OC group during phase 1, $F(1,34) = 5.04$, $MSE = 1.76$, $p = .03$, Eta squared = 0.13, reflecting poorer performance on the novel task (without the biofeedback monitor).

To examine our prediction regarding the differential effect of biofeedback on the two groups, we performed three interaction contrasts: High vs. low OC tendencies and viewing vs. not viewing the monitor (P2 vs. P1 and P3), high vs. low OC tendencies and phase 1 vs. phase 2, and high vs. low OC tendencies and phase 2 vs. phase 3. The first interaction contrast was significant, $F(1,34) = 11.00$, $MSE = 0.58$, $p = .002$, Eta squared = 0.24, demonstrating a different effect of viewing the monitor on the two groups. The second interaction contrast was also significant, $F(1,34) = 7.37$, $MSE = 0.98$, $p = .01$, Eta squared = 0.18, indicating that the performance of the high OC participants improved more than that of the low OC participants when the biofeedback monitor was introduced. Finally, the third interaction contrast was also significant, $F(1,34) = 5.01$, $MSE = 0.56$, $p = .03$, Eta squared = 0.13, reflecting the reverse effect when the biofeedback monitor was withdrawn.

We conducted a two-tail independent sample *t*-test to examine the prediction that high OC participants would be more inclined than low OC participants to request the biofeedback monitor during phase 4. Consistent with this prediction, high OC participants asked to see the monitor more times ($M = 4.39$, $SD = 1.79$) than did the low OC participants ($M = 2.06$, $SD = 1.7$), $t(34) = 4.02$, $p < .001$, reflecting less confidence in their performance.

4. Discussion

The present study examined the possibility that inputs from internal states in OCD are attenuated, so that the reduced subjective conviction of OC individuals is grounded in a real deficiency in perceiving and experiencing internal states. We examined this hypothesis using a magnitude production task, in which muscle tension was used as the internal state and a biofeedback monitor was used as a proxy.

The results were in line with our predictions. In the absence of biofeedback, high OC participants, compared to low OC participants, were less accurate in producing specific muscle tension levels. When an external proxy for muscle tension was provided via the biofeedback monitor, the difference in performance between the two groups was eliminated. In addition, high OC individuals were more likely than low OC individuals to request the biofeedback proxy, which demonstrates their reluctance to rely on their own judgment in regard to this particular internal state.

As accurate perception is necessary for accurate production of specific levels of muscle tension, the poorer performance of high OC participants in the absence of biofeedback is consistent with the possibility of a real deficiency in perceiving and experiencing internal states. In the present paradigm, this deficiency could be compensated for by relying on the biofeedback monitor. Accordingly, high OC participants chose to rely on this previously-learned and useful proxy, whereas low OC participants, who presumably have intact access their internal states and are more confident in their assessment of these states, did not feel the need to rely on this proxy.

The results of this study replicate and extend the findings from Lazarov et al. (2010, 2011). Whereas in our previous studies the requirement was to relax deeply, a task that might be related to anxiety and to OC tendencies, participants in the present study were requested to produce different levels of muscle tension, a requirement unrelated to relaxation ability.[1]

[1] Note that even the lowest muscle tension target of 4 μv required muscle contraction and was distinctly different from relaxation levels as indicated by the baseline EMG readings ($M = 1.15$, ranging from 0.63 to 2.45).

The present results support the possibility that the reliance of OC individuals on proxies for internal states may be justified, in the sense that their access to and experience of these internal states appears to be deficient. Hence, the problem of doubt in OCD could be understood not as an irrational lack of conviction in regard to internal states but rather as reflecting a real deficiency in accessing, experiencing or monitoring internal states.

Our findings are consistent with previous accounts of OCD in some respects, but extend and diverge from them in others. First, our results are in line with previous descriptions of the pervasiveness of doubt in OCD (Janet, 1903; Rapoport, 1989; Reed, 1985; Shapiro, 1965). In this study, uncertainty regarding performance was reflected by the number of requests to see the biofeedback monitor during the fourth phase of the experiment. We believe it to be a more accurate measure of doubt and uncertainty compared to verbal subjective evaluations, which have yielded inconsistent results (e.g., Cabrera, McNally, & Savage, 2001; Moritz, Jacobsen, Willenborg, Jelinek, & Fricke, 2006; Moritz, Kloss, Vitzthum von Eckstaedt, & Jelinek, 2009; Moritz, Ruhe, Jelinek, & Naber, 2009; Tekcan, Topçuoğlu, & Kaya, 2007).

Specifically, these findings extend previous findings regarding mistrust in general memory abilities, decision making, concentration abilities, attention and perception in OCD to include more general internal states. More importantly, our findings agree with recent models postulating a real deficiency or malfunction in OCD individuals in generating and experiencing internal states and feelings, such as a "feeling of knowing" (Summerfeldt, 2004, 2007; Szechtman & Woody, 2004) or "satiety feedback feelings" (Boyer & Lienard, 2006). Our findings supplement these models in suggesting that OC individuals seek, use and rely on proxies as a compensation strategy designed to overcome doubts emanating from attenuation of direct experience. In addition, we expand the proposed deficiency to non-security-related areas and to internal states not related to incompleteness, postulating a more general deficiency in accessing internal states. Finally, our results support OCD models postulating a reliance on external objective cues as possible indicators of an elusive internal "feeling of rightness" (Wahl et al., 2008). In line with these models, we believe that this may be a general strategy that is not limited to inflated responsibility or to specific OC concerns.

We should note several limitations of this study. First, our findings are based on a non-clinical, highly functioning, largely female student sample and their generalization to OCD requires replication with a sample of OCD patients. Second, individuals with high and low OC tendencies are very likely to differ also on trait anxiety and perhaps other psychopathology, which constitutes a limitation and a possible alternative explanation for our results. Specifically, the current task required not only detection of internal signals but also performance (i.e., producing different muscle-tension levels). Interference in performance by task-irrelevant processing has been documented in anxious populations (e.g., Cassiday, McNally, & Zeitlin, 1992; Dawkins & Furnham, 1989). We are presently implementing the same procedure with a clinical population of OCD patients, anxiety patients with no OC symptoms and matched control participants in an attempt to address these shortcomings.

Future research could explore our hypothesis by examining other proxies, less objective and valid than biofeedback, and different internal states, ranging from basic sensations, such as hunger or pain, to more complex subjective experiences, such as affective states. In addition, we know very little about why and how the hypothesized deficiency in accessing and experiencing internal states can expresses itself in specific domains of doubt and uncertainty. Why it is that one individual experiences doubt in regard to locking the door, another with regard to the cleanness of her hands, and still another with regard to his level of understanding? The answer may be related to the subjective importance of the relevant domain or the sense of responsibility the individual feels in regard to that domain (Salkovskis, 1999; Wahl et al., 2008). Future research can examine how reliance on proxies varies with the relevance of the domain, the perceived seriousness of making a mistake or the presence of threat. Finally, deficient detection of internal states has been advanced to explain other psychopathology-related phenomena. These include deficient decision making due to a dysfunctional biological-somatic marker (Bechara & Damasio, 2004), as seen in antisocial behaviors (e.g., Sinclair & Gansler, 2006; Sobhani & Bechare, 2011), addiction (e.g., Verdejo-García & Bechara, 2009; Verdejo-García, Pérez-García, & Bechara, 2006) and OCD (Cavedini et al., 2012; Stracke et al., 2009), and confusion regarding hunger awareness as seen in Anorexia Nervosa (Bruch, 1980, 1981). Further work is needed to clarify the conditions leading to OCD, on the one hand, and to outline the common features shared by these disorders, such as preferring short term benefits over long term ones, on the other.

To the extent that the SPIS hypothesis is validated, it may have important implications for cognitive and meta-cognitive therapy for OCD. Doubts and uncertainty can be understood in therapy not only as excessive and irrational but also, in part, as emanating from deficient access to internal signals. Rules and rituals can be reframed as more discernible and less ambiguous substitutes (i.e., proxies), designed to compensate for these difficult-to-access internal signals. The potential complications inherent in this compensation strategy can be explained to patients, together with mechanisms that further undermine conviction and can lead to vicious cycles, such as repeatedly questioning and examining their own feelings and preferences. More speculatively, biofeedback procedures may be used to help patients learn to identify and control basic internal states such as muscle tension or anxiety, and perhaps to generalize this learning to other internal states in regard to which the patient experiences doubt and uncertainty.

Acknowledgments

This research was supported by the Israel Science Foundation (Grant number 1156/11). The funding agency had no role in the study design; in the collection, analysis and interpretation of data; in the writing of the report; or in the decision to submit the article for publication.

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