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Andrea L. Hinds, Erik Z. Woody, Louis A. Schmidt, Michael Van Ameringen, Dr. Henry Szechtman

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IN THE WAKE OF A POSSIBLE MISTAKE: SECURITY MOTIVATION, CHECKING BEHAVIOR, AND OCD

Andrea L Hinds[1*], Erik Z Woody[2], Louis A Schmidt[3], Michael Van Ameringen[1], and Henry Szechtman[1]§

[1] Department of Psychiatry & Behavioural Neurosciences, McMaster University

[2] Department of Psychology, University of Waterloo

[3] Department of Psychology, Neuroscience & Behaviour, McMaster University

[*]Current address: UB Orthopedics & Sports Medicine, Buffalo, New York, USA

§Correspondence:
Dr. H Szechtman
Department of Psychiatry and Behavioral Neurosciences
McMaster University
1280 Main Street West
Health Science Centre, Room 4N82
Hamilton, Ontario
CANADA L8S 4K1
Tel: (905) 525-9140 ext 22201
FAX: (905) 522-8804
Email: szechtma@mcmaster.ca

Abstract

Background and Objectives: **I**n previous experiments, OCD washers did not differ significantly from controls in their initial level of activation in response to the potential threat of contamination; however, they were less able to reduce their activation by engaging in hand-washing, suggesting that the key problem in OCD is a faulty stopping mechanism. The main objectives of the present experiments were to develop a similar experimental paradigm for investigating checking behavior, and to use it to test the hypothesis that a faulty stopping mechanism also underlies OCD checking.

Methods: Participants sorted pills under the guise of beta testing a new medication system and then were given suggestions of the possibility of having made mistakes with potentially serious consequences. Later, participants engaged in a 90-second checking period and an unlimited period of checking. At baseline and three other times during the experiment, security motivation was measured with respiratory sinus arrhythmia (RSA) and subjective ratings of confidence. Experiment 1 established the parameters of the paradigm in non-patient participants, and Experiment 2 contrasted OCD checkers with OCD washers and non-patients.

Results: Results for both subjective and physiological measures of security motivation closely replicated previous findings for washing behavior. Groups did not differ significantly in initial activation, but the OCD checkers were unable to reduce their activation by engaging in period of checking that was ample for returning controls to baseline.

Limitations: The sample size for the patient groups was modest.

Conclusions: These results lend further support to the security-motivation theory of OCD.

KEYWORDS

Security motivation; obsessive-compulsive disorder (OCD); potential danger; pill-sort checking paradigm; stopping mechanism; heart-rate variability

1. INTRODUCTION

In obsessive-compulsive disorder (OCD), people feel driven to engage repeatedly and excessively in particular security-related behaviors, such as washing their hands or checking their work for mistakes. However, aside from their intensity and persistence, such compulsions are closely akin to normal security-related behavior (Boyer & Lienard, 2006; Reed, 1985; Wise & Rapoport, 1989). Based partly on this insight, Szechtman and Woody (2004) hypothesized that OCD represents a dysfunction of a biologically primal system, the security motivation system (SMS), which normally works to protect individuals from potential dangers, such as contamination by disease or vulnerability to predator attack. The detection of cues, even subtle or relatively weak ones, suggesting potential threat activates this system, which motivates the performance of relevant preventative behaviors such as washing and checking. In turn, the engagement in these behaviors typically supplies the negative feedback that shuts down security motivation.

Building on the work of Reed (1977, 1985), Szechtman and Woody (2004) proposed that the symptoms of OCD stem from the breakdown of this negative feedback mechanism. Specifically, in OCD the performance of preventative behaviors fails to generate a satiety-like phenomenological signal of task completion, so that activated security motivation does not terminate in the normal way. Because of this failure of the shut-down mechanism, security motivation persists for an abnormal length of time and drives compulsive and obsessive behaviors. In short, according to this theory, OCD stems from dysregulation of a normal motivational system that handles potential threat (see also Abed & de Pauw, 1998; Boyer & Bergstrom, 2011; Flannelly, Galek, Tannenbaum, & Handzo, 2007; Neuberg, Kenrick, & Schaller, 2011; Tooby & Cosmides, 2006; Trower, Gilbert, & Sherling, 1990).

1.1 PREVIOUS EMPIRICAL STUDY OF THE SECURITY MOTIVATION SYSTEM

To evaluate the SMS theory as an explanation of OCD behavior, we conducted a set of experiments to investigate washing as the preventative behavior in response to the

potential threat of contamination. In non-patient individuals, we showed that potential threat evoked by placing one's hand in a bin of dirty diapers produced a marked state of activation, which was quite persistent in the absence of preventative behavior (Hinds, et al., 2010). However, the preventative behavior of hand-washing quickly returned this activation to baseline. In contrast, cognitive reappraisal after contact was ineffective in reducing activation, supporting the hypothesis that the actual performance of security-related behaviors normally plays a crucial role in the deactivation of the SMS.

In subsequent studies, we used the same experimental paradigm to examine the nature of washing behavior in OCD patients (Hinds, Woody, Van Ameringen, Schmidt, & Szechtman, 2012). OCD patients with washing as their predominant symptom did not differ significantly from non-patients in their initial level of activation in response to the potential threat of contamination. This finding was consistent with the SMS theory of OCD, which does not propose a hypersensitivity to potential-danger cues in OCD. However, the OCD washers were significantly less able to reduce their activation by engaging in the preventative behavior of hand-washing. This result lent crucial support to hypothesis of the SMS theory that the key problem in OCD is a faulty stopping mechanism. Finally, we found that OCD patients with checking as their predominant symptom were just as able as non-patients to reduce their activation by engaging in hand-washing, suggesting that the dysfunction of termination in OCD may be specific to the patient's particular symptom profile.

1.2 RESPIRATORY SINUS ARRHYTHMIA AS AN INDEX OF THE ACTIVATION OF THE SECURITY MOTIVATION

In addition to collecting participants' subjective ratings in the foregoing experiments, we employed respiratory sinus arrhythmia (RSA) as a physiologically based, objective measure of the activation of security motivation. According to Polyvagal theory (Porges, 2007), there is a hierarchy of states of parasympathetic-sympathetic functioning: A state dominated by parasympathetic influence facilitates social behavior in circumstances that are safe from danger, whereas a state dominated by sympathetic influence

facilitates fight-or-flight behavior in circumstances that present imminent danger. Between these is an intermediate state that occurs when attention is drawn to the environment because of potential threat or novelty, in which parasympathetic influence is reduced, so that the sympathetic system can be triggered quickly if required later.

This potential-threat state of autonomic function can be monitored by its characteristic effect on heart-rate variability, reflecting the influence of a vagal brake on the cardiac pacemaker (Porges, 2007). Removal of this brake makes the heart's inter-beat interval less modulated and hence more regular, yielding decreased RSA amplitude (measured in *ln msec*^{2}), which thus indicates a shift from a safe toward a potential-threat autonomic state. For a more detailed explanation of the rationale for RSA, see Woody and Szechtman (2011).

1.3 CHECKING BEHAVIOR

As mentioned earlier, our previous work evaluating the operation of the hypothesized security motivation system in both non-patient individuals and OCD patients has focused on the behavior of washing, as associated with the potential threat of contamination (Hinds, et al., 2010; Hinds, et al., 2012). Another very important and common type of OCD behavior is checking, which is associated with potential threats such as the possibility of having left a door unlocked or an oven on, or having made some other kind of potentially costly mistake. In addition to the importance of checking compulsions in OCD, the scientific literature on security-related responses to potential-threat cues treats checking behavior as paradigmatic (e.g., Blanchard & Blanchard, 1988; Blanchard, Griebel, Pobbe, & Blanchard, 2011; Boyer & Lienard, 2006; Kavaliers & Choleris, 2001; Wise & Rapoport, 1989). However, despite the importance of checking behavior for a fuller understanding of both the normal and abnormal operation of the security motivation system, checking has not yet been studied using this framework. Hence, the overarching objective of the work reported here was to evaluate whether the results of experiments investigating checking behavior would lend support to the

security motivation theory, importantly complementing our previous results involving washing behavior.

2 EXPERIMENT 1

The purpose of Experiment 1 was to evaluate whether the elicitation and effects of checking behavior in non-patient individuals are consistent with hypothesis of an underlying security motivation system, in parallel to what we have previously shown for washing behavior (Hinds, et al., 2010; Hinds, et al., 2012). We had 4 specific goals for this experiment:

1. To show that it is possible to devise a checking-related experimental paradigm that evokes activation of the security motivation system, as indicated by participants' RSA levels. For this purpose, we used a task, based on the work of Arntz, Voncken and Goosen (2007), in which participants sort pills under the guise of beta testing a new medication system.
2. To show that this pill-sorting paradigm also affects participants' relevant subjective experience. Unlike our previous studies of washing behavior, for which a subjective sense like possible contamination is particularly relevant, for checking behavior the relevant subjective sense may be lack of confidence that one did not make any mistakes.
3. To demonstrate that it is the potential-danger aspect of the pill-sorting paradigm that evokes the foregoing responses, rather than other, incidental aspects of it. For this purpose, we compared the pill-sorting task to a candy-sorting task with the same structure, but no stimuli suggesting potential danger.
4. To test the hypothesis that once security motivation is activated, the performance of checking behavior acts to terminate this activation, as shown by RSA and subjective confidence returning to near-baseline levels. We also sought to establish the typical duration of checking sufficient to terminate

security motivation in people without OCD symptoms, as a benchmark for use in the subsequent experiment with OCD patients.

2.1 METHOD

2.1.1 PARTICIPANTS

Participants were 88 (64 female and 24 male) individuals recruited in a university hospital setting. They ranged in age from 18 to 65, with a mean of 29.2 years (SD = 5.4), and their mean body weight and height were 62.5 kg (SD = 9.6) and height 1.69 m (SD = 0.08). All participants were pre-screened to check that they reported no known diagnosis or treatment for mood or behavioral disorders, no problems involving heart or lung function, and no regular experience with the handling and sorting of medications. They were required not to ingest coffee or other stimulants for at least 2 hours prior to the study. Participants were randomly assigned to the four experimental conditions, subject to maintaining a comparable proportion of genders in each group and a larger sample for the Pill-Sorting condition (given that this condition was to be used in the second experiment and hence greater precision about its effects was desirable). Seventeen participants were assigned to each of the Candy-Sorting groups (Check vs. Delayed-Check, with 12 women and 5 men in each group), and 27 participants were assigned to each of the Pill-Sorting groups (again, Check vs. Delayed-Check, with 20 women and 7 men in each group). At the conclusion of the experiment, participants were asked to complete the Padua-R inventory of compulsive behaviors (Burns, Keortge, Formea, & Sternberger, 1996) to ensure that no participants had unusually high checking-related concerns. The study was approved by the McMaster University and Hamilton Health Sciences Institutional Review Board.

2.1.2 MATERIALS & APPARATUS

Participants in the Pill-Sorting condition were presented with seven vials of pills of three different colors (blue, pink, and white), to be sorted into daily doses in a weekly pillbox,

according to instructions described below. Participants in the Candy-Sorting condition performed the same kind of task, but with colored candies. During the subsequent, checking-related phase of the experiment, RSA was measured by the continuous monitoring of ECG using the Biopac Acquisition System, sampling at 2000 Hz. For each participant a data file of interbeat intervals was created, and the software CardioBatch and CardioEdit were applied to these data to derive RSA values, in accordance with the protocol developed by Porges and colleagues (Porges, 2007; Porges & Byrne, 1992).

2.1.3 PROCEDURE

In the pill-sorting condition, participants arranged an assortment of medications according to specific dosing instructions. The experimenter told participants that they were serving as beta testers of a suggested new method for sorting medications to reduce serious reactions that may be associated with unintentional dosing errors. Emphasis was placed on the responsibility of the participant to provide important information about the new method, and its feasibility for implementation. According to this system, dosing time is identified by pill color: pills colored pink were to be identified as a morning dose, white as an afternoon dose, and blue as an evening dose. Participants were given seven vials, each containing one month's worth of a hypothetical "prescription" consisting of pills of some combination of the three colors. Participants were to follow instructions for sorting the pills into seven daily doses (for example, one pill, to be administered three times per day) into a provided pillbox.

In the candy-sorting condition, participants performed an exactly parallel task, but it involved using the rules to sort colored candies, and, unlike the pill-sorting condition, the instructions made no mention of importance or responsibility. In both conditions, participants were told to work as quickly and accurately as possible, and to inform the experimenter when they felt the task was complete.

Upon completion, the sorted objects were temporarily set aside. The experimenter then attached electrodes for measuring ECG and asked participants to close their eyes,

sit still, and relax during a two–minute baseline, while data for calculating RSA were collected.

Next, the experimenter told participants to open their eyes, handed the previously sorted objects back to participants, and asked them to place them on their lap. They were asked to remember and reflect back on the sorting phase of the study. In the pill-sorting condition, these instructions were designed to evoke a sense of potential danger and the motivation to check, as follows:

> *Think back to the Beta test that you completed earlier. I want to give you some more information about the Beta testing. The groups of patients of particular interest for this program are those with cancer. Often, cancer patients or their caregivers must administer combinations of medications that can have very serious health consequences if not taken properly. Children are especially vulnerable to dosing errors, and their caregivers do not often have previous experience distributing medications. In a previous study to test the effectiveness of the pill sorting procedure, the results were alarming – participants in the test made many mistakes. After reviewing the data, we found that the task is harder to do correctly than people think it is. We also know that people's memory of completing an important task can be flawed – for example, believing that something was done correctly (i.e. turning off a stove, or locking the door) when in fact, it was not. Often, participants believed that they had done the task perfectly, and were surprised to find that they had made potentially dangerous mistakes. In the rest of this experiment, we want you to help us improve the pill sorting procedure so that people don't make dangerous, and even potentially fatal, mistakes.*

In contrast, in the candy-sorting condition, the instructions were simply to "think back to the sorting you completed earlier. In the rest of this experiment, we want you to help us improve the sorting procedure so that people don't make mistakes."

All participants were then told to close their eyes and sit still for two minutes, thinking back to their performance on the sorting task with the sorted objects remaining on their lap, during which ECG data were again collected. Participants were also asked, "How confident are you right now that you completed the sorting test correctly, without making any mistakes?" In response, participants pointed to a position along a 15 cm line, with the end-points labeled "not confident at all (I am sure I made a mistake)" and "extremely confident (I am sure I did not make a mistake)." This response was scored as a distance in millimeters from the low end-point.

At this point, all participants were told, "It would be nice to check for any errors you might have made." Participants in the Check condition were then permitted to check over their sorting (of either pills or candies). To assist them in this task, the experimenter provided them with a sample assortment that showed the correct solution. Participants were given 90 seconds to perform the checking, enough time to easily confirm their accuracy. In the Delayed-Check condition, participants were simply asked to continue sitting quietly for the 90 seconds, without being allowed to check. After the 90 seconds, participants closed their eyes and another two-minute sample of ECG data was collected, and then they again rated their subjective experience (as described previously).

Next, participants were told, "Now, for whatever amount of time you need, you may check your pillbox (or candies) for accuracy. Take as long as you want." The experimenter recorded the amount of time the participant spent checking. Finally, a last two-minute period of ECG data was collected, and participants made a final rating of their subjective experience.

2.2 RESULTS

The crucial data in this experiment are the RSA values at three times of measurement: (1) after the participant is asked to think back on the sorting task; (2) after the 90-second prescribed behaviour (Check vs. Delayed-Check); and (3) after the unlimited period of checking at the end of the experiment. For each participant, the RSA values at these 3 times were subtracted from the participant's baseline RSA, so that higher scores indicate greater levels of SMS activation.

These RSA change data were analyzed with multivariate analysis of covariance (MANCOVA), using baseline RSA, age, and sex as covariates. Note that the statistical tests for RSA change using baseline RSA as a covariate are identical to the corresponding tests for raw RSA using baseline RSA as a covariate; the advantage of using RSA change is solely to express decreases in RSA as increases in SMS activation. In the MANCOVA, there were two between-subject factors, Type of Sort (Pill vs. Candy) and Prescribed Task (90-s Check vs. Delayed-Check), and one within-subject factor, Time of Measurement, with three levels (After Recall, After Prescribed Task, and After Free Check).

For RSA change, the expected three-way interaction of Type of Sort, Prescribed Task, and Time of Measurement was statistically significant, $F(2, 80) = 36.97$, $p <. 001$, partial eta-squared = .48. This three-way interaction qualified several other statistically significant effects: the two-way interactions of Type of Sort and Time of Measurement, $F(2, 80) = 86.66$, $p < .001$; of Prescribed Task and Time of Measurement, $F(2, 80) = 49.51$, $p < .001$; and of Type of Sort and Prescribed Task, $F(1, 81) = 12.76$, $p < .001$; and the main effects of Type of Sort, $F(1, 81) = 156.81$, $p < .001$; and of Prescribed Task, $F(1, 81) = 13.93$. $p < .001$.

The left panel of Figure 1 portrays the relevant adjusted means. At the first time of measurement, after recall of the sorting task, both pill-sorting groups showed significantly higher SMS activation than both candy-sorting groups. This large difference indicates that reflection on the pill-sorting task elicits potential danger, as intended, whereas reflection on the candy-sorting task does not. At the second time of

measurement, after the prescribed task, the pill-sorters in the delayed-check condition showed significantly higher SMS activation than the other 3 groups; in contrast, the pill-sorters allowed to check for up to 90 s dropped in activation to a level comparable to the candy-sorters. Finally, at the third time of measurement, after the free check, all 4 groups showed comparable, low levels of SMS activation, not differing significantly. In particular, the pill-sorters in the delayed-check condition decreased significantly in SMS level once they were allowed the free check, dropping to a level comparable to that of the other 3 groups.

A MANCOVA analysis was also performed on the participants' subjective ratings of how confident they were that they had done the sorting correctly, without any mistakes. Age and sex were included as covariates in this analysis. As with RSA, this analysis yielded a statistically significant three-way interaction of Type of Sort, Prescribed Task, and Time of Measurement, $F(2, 81) = 29.12$, $p < .001$, partial eta-squared = .42. This three-way interaction qualified several other statistically significant effects: the two-way interactions of Type of Sort and Time of Measurement, $F(2, 81) = 33.48$, $p < .001$; and of Prescribed Task and Time of Measurement, $F(2, 81) = 44.43$, $p < .001$; and the main effects of Type of Sort, $F(1, 82) = 52.33$, $p < .001$; and of Prescribed Task, $F(1, 82) = 8.20$, $p < .01$.

The right panel of Figure 1 shows the adjusted means relevant to these effects. After recall of the sorting task, both pill-sorting groups showed significantly lower confidence than both candy-sorting groups. After the prescribed task, the pill-sorters in the delayed-check condition were significantly lower in confidence than the other 3 groups, whereas their counterparts allowed to check for up to 90 s became extremely confident. Lastly, after the free check, once the pill-sorters in the delayed-check condition had finally been allowed to check, all 4 groups attained comparable, extremely high levels of confidence. This pattern of findings for subjective experience exactly mirrors the foregoing physiologically based results for RSA.

A further variable of some interest is the actual amount of time that participants spent checking during the 90-second fixed check and during the final free check. For participants in the delayed-check condition, the duration of checking during the fixed check was necessarily zero; thus, there are cells in the full design with no data for this variable. However, checking duration can be examined with two separate analyses, each corresponding to subordinate designs with data in all cells. The first analysis looked at checking duration in the participants who did both the fixed and the free checks. This MANCOVA, with Type of Sort and Time of Measurement as the factors and age and sex as covariates, yielded a statistically significant two-way interaction of Type of Sort and Time of Measurement, $F(1, 40) = 93.14$, $p < .001$, partial eta-squared = .70. This interaction qualified statistically significant main effects of Type of Sort, $F(1, 40) = 233.82$, $p < .001$; and Time of Measurement, $F(1, 40) = 14.98$, $p < .001$. The relevant means showed that checking duration was significantly longer for the pill-sorters than for the candy-sorters, both for the fixed check (adjusted means = 66.4 s vs. 28.7 s) and for the subsequent free check (24.8 s vs. 16.5 s); however, this difference in duration of check was significantly larger for the fixed check than for the free check. This pattern of results indicates that, as expected, the pill-sorting task evoked longer checking than the candy-sorting task, and the decrease in this difference at the second opportunity to check presumably occurred because the previous fixed check was largely sufficient to deactivate the sense of potential danger evoked by the pill-sorting task.

The second analysis compared the duration of the free check for participants who had versus had not previously done a fixed check. This MANCOVA, with Type of Sort and Prescribed Task as the factors and age and sex as covariates, yielded a statistically significant two-way interaction of Type of Sort and Prescribed Task, $F(1, 82) = 112.38$, $p < .001$, partial eta-squared = .58. This interaction qualified statistically significant main effects of Type of Sort, $F(1, 82) = 258.65$, $p < .001$; and Prescribed Task, $F(1, 82) = 324.49$, $p < .001$. The means showed that the duration of the free check was significantly shorter when it followed a previous check than when it did not, both for the pill-sorters (adjusted means = 24.9 s vs. 68.8 s) and for the candy-sorters (16.4 s vs. 28.0 s);

however, this difference was significantly larger for the pill-sorters. These purely between-subject effects have the same implications as the results of the foregoing analysis—in particular, they suggest that a previous fixed check was largely sufficient to dissipate the sense of potential danger evoked by the pill-sorting task.

2.3 DISCUSSION

The results of Experiment 1 with checking behavior closely parallel our previous findings with washing behavior (Hinds, et al., 2010), and hence they lend further support to the hypothesis that a security motivation system underlies the elicitation and feedback function of such potential-danger-related behaviors. In particular, the suggestion that there could be mistakes in one's work on a task associated with potentially dangerous outcomes successfully activated security motivation, as shown in both the RSA levels and the subjective ratings of confidence. A very similar control task that omitted information suggesting potential danger did not produce these outcomes, supporting the hypothesis that it was specifically potential danger that elicited these SMS-related changes. Subsequently engaging in checking behavior quickly returned RSA and subjective confidence to baseline levels, consistent with the hypothesis that it is the performance of such preventative behavior that shuts down activated security motivation. The results also indicate that in this paradigm non-patient participants require only a minute to a minute and a half of checking behavior to terminate the activation of security motivation.

3 EXPERIMENT 2

Although the security-motivation-system theory has important general implications (Woody & Boyer, 2011; Woody & Szechtman, 2006, 2013), our previous work has emphasized the hypothesis that a dysfunction of this system is the underlying cause of OCD (Hinds, et al., 2012; Szechtman & Woody, 2004; Szechtman & Woody, 2006; Woody & Szechtman, 2005). Hence, in Experiment 2, we used the pill-sorting paradigm, together with the 90-second fixed check and subsequent free check, to examine the

nature of checking behavior in OCD patients. More specifically, we compared the behavior of OCD patients with checking as their main symptom to the behavior of two other groups of participants: OCD patients with washing as their main symptom, and non-patients controls.

There were 3 specific goals for Experiment 2:

1. To shed further light on the hypothesis, advanced by Taylor, McKay, and Abramowitz (2005), that OCD symptoms, including checking, stem from a pathological intensity of excitation by stimuli suggesting potential danger, what we have termed a "starting problem" (Hinds, et al., 2012). Our previous findings for washing behavior in OCD patients do not support this hypothesis of a starting problem, in that the level of activation in response to possible contamination was roughly comparable for OCD washers and non-patients. However, it is possible that a starting problem might be more evident in OCD checkers.

2. To test the hypothesis, derived from the security-motivation-theory of OCD, that OCD symptoms such as compulsive checking represent a dysfunction in the normal termination of security motivation through engaging in preventative behavior, what we have termed a "stopping problem." If this hypothesis is correct, then checking sufficient to deactivate security motivation in non-patients should instead produce negligible deactivation in OCD checkers.

3. To investigate whether this stopping problem in OCD is specific to the patient's predominant symptom, rather than more general. In a previous study of washing behavior following a potential threat of contamination, we found that OCD patients with a primary symptom of checking did not show the stopping problem found in OCD patients with a primary symptom of washing, and instead closely resembled non-patient controls (Hinds, et al.,

2012). Hence, in this experiment we wanted to evaluate the comparable specificity hypothesis—namely, that the low effectiveness of checking behavior to terminate the activation of security motivation would distinguish OCD patients with a primary symptom of checking from OCD patients with a primary symptom of washing, who in turn should resemble non-patients.

3.1 METHOD

3.1.1 PARTICIPANTS

Participants, recruited in a university hospital setting, were 8 OCD patients with checking as the predominant symptom, 7 OCD patients with washing as the predominant symptom, and 8 non-patient controls. Each group included 2 male participants. Participants ranged in age from 23 to 51, with a mean of 32.7 years (SD = 7.5), and their mean body weight and height were 68.3 kg (SD = 9.7) and height 1.69 m (SD = 0.09).

All patient participants had a primary diagnosis of OCD, based on either the Structured Clinical Interview for DSM-IV (SCID; First, Spitzer, Gibbon, & Williams, 2002) or the Mini-International Neuropsychiatric Interview (MINI; Sheehan, et al., 1998); and diagnostic status was confirmed by an experienced clinician (MVA). The patients had as their primary symptom either contamination/washing or checking, but not both. The non-patient participants were recruited to match the gender and age distribution of the patients and were pre-screened as having no known psychiatric disorders. As a further check on the symptom profiles of the three participant groups, the Padua-R (Burns, et al., 1996) was administered to all participants. On the checking subscale of the Padua-R, the OCD checkers scored much higher than the OCD washers and the non-patients (means = 24.38, 10.57, and 7.75, respectively). Likewise, on the contamination subscale, the OCD washers scored substantially higher than the OCD checkers and the non-patients (means = 18.29, 9.88, and 5.63, respectively). On the Padua-R total score, the non-patients scored much lower than both the OCD washers and checkers (means =

20.13, 36.57, and 44.75, respectively); however, the difference between the two groups of OCD patients was also statistically significant, suggesting that the checkers may have had somewhat more severe OCD overall. Because of this potential confound and the modest sample size, the results of this experiment should be regarded as a "point-of-principle" demonstration, rather than a definitive empirical test of the hypotheses.

3.1.2 MATERIALS & APPARATUS

Materials and apparatus were the same as in Experiment 1 (but with no candies).

3.1.3 PROCEDURE

All participants in Experiment 2 were run in the Pill-Sorting, 90-second Fixed Check combination of Experiment 1, exactly as described above. That is, all participants performed the beta-testing pill sort task, were given the recall instructions designed to activate the sense of potential danger and motivation to check, were then asked to engage in a 90-second fixed check, and later, toward the end of the experiment, were allowed a further, free check for as long as they wanted. Collection of RSA and subjective experience data at the various times of measurement was exactly as in Experiment 1. The setting and experimenter were also the same for the two experiments, which should help to ensure comparability of effects between the studies.

3.2 RESULTS

As in Experiment 1, the crucial data in this experiment are the RSA values at three times of measurement: (1) after the participant is asked to think back on the pill-sorting task; (2) after the 90-second prescribed check; and (3) after the unlimited period of checking at the end of the experiment. As in Experiment 1, for each participant the RSA values at these 3 times were subtracted from the participant's baseline RSA, so that higher scores indicate greater levels of SMS activation.

These RSA change data were analyzed with multivariate analysis of covariance (MANCOVA), baseline RSA, age, and sex as covariates. There was one between-group factor, OCD Status (OCD Checkers, OCD Washers, and Non-Patients), and one within-subject factor, Time of Measurement (After Recall, After Prescribed Task, and After Free Check). Statistical tests were based on Pillai's trace. The predicted interaction of OCD Status with Time of Measurement was clearly obtained, $F(4, 34) = 5.46$, $p < .01$, partial eta-squared = .39. There were no other statistically significant effects involving main effects of the two factors or their interactions with the covariates.

The left panel of Figure 2 shows the adjusted means relevant to the obtained two-way interaction. The crucial difference is that after the 90-second prescribed check, RSA change for the OCD checkers is significantly greater than that for the other two groups. After the 90-second check, the level of SMS activation remained high in the OCD checkers, indicating that the fixed period of checking was inadequate for terminating this activation for them. In contrast, the SMS activation of the OCD washers and the non-patients decreased substantially, closely approaching their baseline, indicating that the fixed period of checking terminated SMS activation for them. It is only after the following free wash that the OCD washers show a low level of SMS activation, akin to that of the other two groups.

A MANCOVA analysis was also performed on the participants' subjective ratings of how confident they were that they had done the sorting correctly, without any mistakes. Age and sex were included as covariates in this analysis. As with RSA, this analysis yielded a statistically significant interaction of OCD Status with Time of Measurement, $F(4, 36) = 4.92$, $p < .01$, partial eta-squared = .35; there was also a significant main effect of OCD Status, $F(2, 18) = 6.66$, $p < .01$, partial eta-squared = .43.

The right panel of Figure 2 shows the adjusted means relevant to these effects. As with RSA, the crucial difference between the groups in subjective confidence occurred after the fixed period of checking, when the OCD checkers had significantly lower confidence than the other two groups. Whereas the 90 seconds of checking made the OCD washers

and non-patients extremely confident they had made no errors, the OCD checkers remained uncertain. This difference is again consistent with the hypothesis that compared to the other two groups, OCD checkers are less able to terminate activated security motivation by engaging in preventative behavior.

As in Experiment 1, a further variable of some interest is the amount of time that participants actually spent checking during the 90-second fixed check and during the final free check. A MANCOVA was performed on these data, with Fixed vs. Free Check as the within-subjects factor, OCD Status as the between-subjects factor, and age and sex as covariates. This analysis yielded one significant source of variance, the main effect of OCD Status, $F(2, 18) = 21.07$, $p < .001$, partial eta-squared = .70. In both the fixed and free checks, the OCD checkers checked significantly longer than the other two groups, who did not differ from each other. During the fixed check, the non-patients and OCD washers tended to finish their checking after about one minute (adjusted means = 60.1 s and 65.6 s, respectively), whereas the OCD checkers tended to use most of the allotted time (adjusted mean = 80.0 s). Thus, even though they had checked longer during the fixed check, the OCD checkers still had higher levels of SMS activation than the other two groups (as shown by both the RSA and subjective confidence data). When later allowed to check further as much as wanted, the OCD checkers again spent substantially more time (adjusted mean = 60.6 s) than the non-patients (25.4 s) and the OCD washers (38.6 s).

3.3 DISCUSSION

The results of Experiment 2 with OCD patients and checking behavior closely parallel our previous findings with OCD patients and washing behavior (Hinds, et al., 2012). First, the groups did not differ significantly in the activation of security motivation after being exposed to cues for potential danger, which is again inconsistent with the hypothesis, advanced by Taylor, McKay, and Abramowitz (2005), that OCD reflects a hypersensitivity to such cues—that is, a starting problem. Parenthetically, the security-motivation theory of OCD does not rule out the possibility that such hypersensitivity could develop

as secondary ways of managing a more fundamental stopping problem (see Woody & Szechtman, 2005, for a discussion). However, our data in the present experiment and earlier studies do not seem to show clear evidence of such hypersensitivity.

Second, the significant difference between the OCD checkers and the other two groups after the 90-second check supports the hypothesis that the OCD checkers have a stopping problem, closely akin to what we have previously demonstrated in OCD washers (Hinds, et al., 2012). In particular, engaging in the 90-second period of checking behavior was significantly less effective for terminating activated security motivation in the OCD checkers. It is instructive to compare RSA level in the OCD checkers after the 90-second check in this experiment to that of the participants in the pill-sort, delayed-check condition in Experiment 1, who had spent the 90 seconds doing nothing at all. In terms of terminating activated security motivation, the 90 seconds of checking by the OCD checkers was no more effective than 90 seconds of doing nothing by the non-patients. These results lend further support to the hypothesis, derived from the security-motivation-theory of OCD, that OCD symptoms represent a dysfunction in the normal termination of security motivation through performance of preventative behavior (Szechtman & Woody, 2004).

Third, the stopping problem shown by the OCD checkers was not shown by the OCD washers, who resembled the non-patient controls. This result is consistent with our earlier findings suggesting that the stopping problem in OCD is specific to the patient's symptom profile (Hinds, et al., 2012). Despite this consistency in results, the present finding is somewhat open to an alternative interpretation: Because the OCD checkers in this experiment had somewhat more severe OCD symptomatology overall than the OCD washers, it is possible that they may have showed more of a stopping problem because of their more severe OCD overall, rather than because of their predominant symptom.

The SMS theory is similar to some other important theories of OCD, such as the Seeking Proxies for Internal States theory (Lazarov, Liberman, Hermesh, & Dar, 2014), in the proposed crucial role of weak internally generated feedback. However, the SMS theory

differs from other theories in its strong distinction between starting versus stopping dynamics, with the underlying deficit in OCD attributed mainly to the latter.

4 CONCLUSIONS

These two experiments represent a successful initial step in bringing the phenomenon of checking behavior empirically within the umbrella of the security motivation theory (Szechtman & Woody, 2004; Woody & Szechtman, 2011). With both non-patient and OCD-patient samples, we were able to obtain effects related to checking that closely parallel those obtained in our earlier studies of washing behavior (Hinds, et al., 2010; Hinds, et al., 2012; Woody, et al., 2005). In particular, consistent with the hypothesis of an underlying security motivation system, cues suggesting the possibility of a mistake in one's work on a task associated with potentially dangerous outcomes activated security motivation, as indicated physiologically by RSA change and subjectively by confidence ratings. Consistent with the hypothesized negative feedback function of engagement in preventative behavior on activated security motivation, a period of checking returned security motivation to baseline for non-patient individuals, as well as for OCD patients with a primary symptom of washing. Finally, consistent with the hypothesis that the symptoms of OCD stem from a dysfunction in the capacity of engagement in preventative behavior to terminate activated security motivation, the same period of checking had virtually no reducing effect on security motivation for the OCD patients with a primary symptom of checking. In contrast, the results did not suggest that OCD stems from a hypersensitivity to cues for potential danger, as alternatively argued by Taylor, McKay, and Abramowitz (2005).

Despite these successes, it is possible that further study of checking behavior in a laboratory setting may be more challenging than the comparable study of washing behavior. Whereas the perception of potential contamination could occur almost anywhere (e.g., including the hospital-based setting of our studies), checking-related concerns may tend to be relatively specific to certain personal settings, such as one's own home or workplace. However, the advancing development of convenient

ambulatory monitoring systems is making the study of checking-related phenomena in non-laboratory settings increasing feasible. Hence, this may be a promising direction for future research.

5 COMPETING INTERESTS

Dr. Hinds, Dr. Woody, Dr. Schmidt, and Dr. Szechtman report no competing interests. In the last 5 years, Dr. Van Ameringen has received research grant support from the Canadian Foundation for Innovation (CFI), Janssen-Ortho Inc., NIH (National Institutes of Health), Pfizer Inc., Shire, and Wyeth-Ayerst. He is a member of the Speaker's Bureau for Biovail, GlaxoSmithKline, Janssen-Ortho Inc., Lundbeck, and Pfizer Inc. He has participated in advisory boards for Astra Zeneca, Biovail, Eli Lilly, Janssen-Ortho Inc., Labo Pharm, Lundbeck, Pfizer Inc., Servier, Shire and Valiant.

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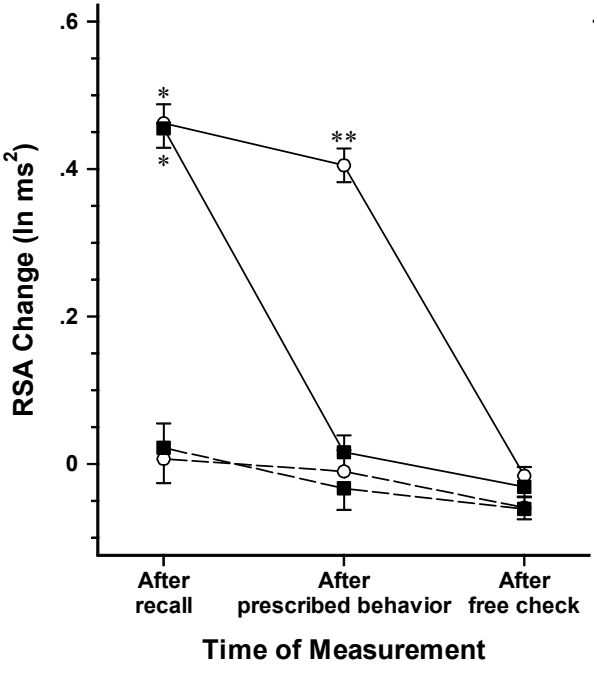
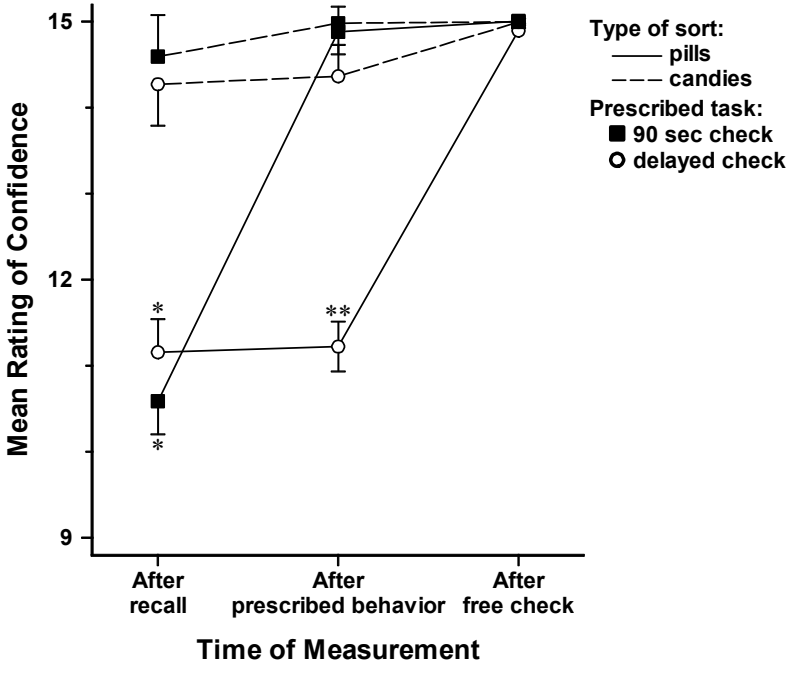
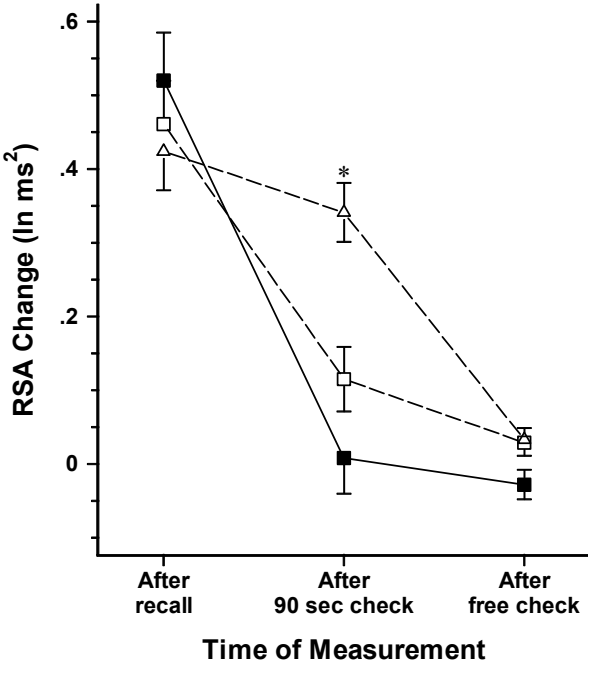
7 FIGURE CAPTIONS

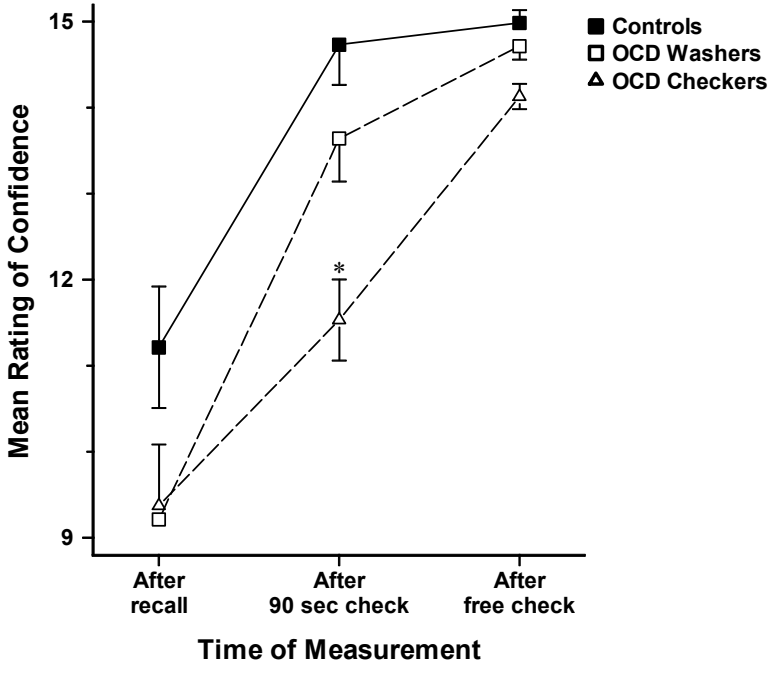
Figure 1 - **RSA change (left panel) and subjective confidence (right panel) as a function of type of sort, prescribed behavior, and time of measurement.** Note: Asterisks indicate the same pattern of significant ($p < .05$) differences for each dependent variable: after recall, both pill-sort groups differed from both candy-sort conditions; and after the prescribed behavior, the pill-sort delayed-check group different from the other three groups. Error bars represent 1 SE.

Figure 2 - **RSA change (left panel) and subjective confidence (right panel) as a function of OCD status and time of measurement.** Note: Asterisks indicate that for each dependent variable, after the 90 s check the OCD checkers differed significantly from the other two groups ($p < .05$). Error bars represent 1 SE.


.6
.4
.2
0
RSA Change (ln ms^2)
*
*
**
After recall
After prescribed behavior
After free check
Time of Measurement


15
12
9
Mean Rating of Confidence
*
*
**
After recall
After prescribed behavior
After free check
Time of Measurement
Type of sort:
pills
candies
Prescribed task:
90 sec check
delayed check


.6
.4
.2
0
RSA Change (ln ms^2)
*
After recall
After 90 sec check
After free check
Time of Measurement


15
12
9
Mean Rating of Confidence
Controls
OCD Washers
OCD Checkers
*
After recall
After 90 sec check
After free check
Time of Measurement

Highlights

- Hand-washing in OCD washers is faulty in reducing activation of security motivation
- A pill-sorting paradigm where checking deactivates security motivation is described
- Checking in OCD checkers was faulty in reducing activation of security motivation
- A faulty stopping mechanism may underlie OCD