INFORMATION PROCESSING AND AFFECTIVE RESPONSES IN HOARDING DISORDER

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ABSTRACT

MICHAEL G. WHEATON: Information Processing and Affective Responses in Hoarding Disorder
(Under the direction of Jonathan S. Abramowitz, PhD)

Hoarding, the accumulation of a large number of possessions and substantial clutter, is increasingly being recognized as an important public health concern. Emerging consensus suggests that hoarding is an independent phenomenon and it will likely be included as a new diagnosis (Hoarding Disorder) in the forthcoming revision to the *DSM*. An initial conceptual model of this condition has implicated information processing deficits and emotional distress as key components of hoarding disorder. Although it has shown promise, this model is in need of greater empirical support and verification. The present study reports on an investigation into information processing and affective responses in relation to hoarding. We compared adults meeting criteria for hoarding disorder (*N*=33) and community controls (*N*=30) using psychophysiological methodologies based on startle eyeblink responses. Prepulse inhibition of startle (PPI), a measure of sensorimotor gating used in previous studies of schizophrenia and OCD, was used to test for information processing deficits proposed to be involved in hoarding symptoms by the cognitive-behavioral model. Affective valence startle modulation (AVSM) was used to elucidate emotional processing in association with hoarding. We also compared hoarding and control group participants on startle reactivity at baseline and while undergoing a symptom-provocation stressor (discarding task). Contrary to our hypothesis, the hoarding and control group participants demonstrated comparable levels of PPI. There were also no group differences when considering comorbid diagnoses. PPI

scores were not related to medication status. AVSM results revealed that both the hoarding and control groups demonstrated a linear pattern of startle modulation to pleasant, neutral and unpleasant stimuli respectively. The hoarding group demonstrated larger general startle reactivity compared to the control group, both at baseline and following the discarding task. We did not find group differences in PPI, indicating that hoarding disorder is not related to sensorimotor gating deficits. The hoarding and control groups had similar affective modulation of startle, but the hoarding group demonstrated higher general startle reactivity. Enhanced general startle suggests that hoarding disorder is characterized by enhanced defensive responding, as is noted in other anxiety disorders such as PTSD and GAD.

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ABBREVIATIONS

APA	American Psychiatric Association
ADHDSS	Attention Deficit/Hyperactivity Disorder Symptom Scale
AVSM	Affective Valence Startle Modulation
CIR	Clutter Image Rating Scale
DASS	Depression Anxiety Stress Scales
DOCS	Dimensional Obsessive-Compulsive Scale
DSM	Diagnostic and Statistical Manual
EMG	Electromyographic
FIS	Frost Indecisiveness Scale
GAD	Generalized Anxiety Disorder
HRS-I	Hoarding Rating Scale-Interview
IAPS	International Affective Picture System
MINI	Mini International Neuropsychiatric Interview
OCD	Obsessive Compulsive Disorder
PPI	Prepulse Inhibition
PTSD	Posttraumatic Stress Disorder
DSM	Diagnostic and Statistical Manual
SCI	Saving Cognitions Inventory
SI-R	Saving Inventory-Revised

INFORMATION PROCESSING AND AFFECTIVE RESPONSES IN HOARDING DISORDER

Hoarding is defined as the acquisition of, and failure to discard, a large number of possessions of apparently limited value (Frost & Gross, 1993). Such possessions accumulate and cause substantial clutter that can interfere with the functionality of an individual's living space, and may represent a health hazard when extreme (e.g., increased risk of fires, poor sanitation; Steketee, Frost, & Kim, 2001). Hoarding also causes significant distress and impairment in functioning, not only for the individual, but also for affected family members, and represents a significant cost to society (Frost, Steketee, & Williams, 2000). In line with the increasing recognition of the importance of hoarding as a public health concern, the past decade has seen a dramatic spike in published reports on hoarding (Mataix-Cols et al., 2010). An initial model of hoarding has implicated information processing deficits and problems with emotional processing as key features of this condition. This model has received preliminary support but more study is needed. Therefore, the present study sought to research two aspects of the model—information-processing and affective responses—in order to advance our understanding of the nature of hoarding as described below.

Diagnostic Classification

Historically, hoarding has often been considered a part of obsessive compulsive disorder (OCD), despite the fact that it is not actually mentioned among the diagnostic criteria for OCD in the *Diagnostic and Statistical Manual of Mental Disorders* (4th ed., text

revision; DSM-IV-TR; American Psychiatric Association [APA], 2000). Increasing evidence has challenged this association and suggests that hoarding is an independent condition in need of its own conceptualization. For example, compared to the cardinal symptoms of OCD (i.e., washing, checking), hoarding symptoms appear to be associated with distinct neural correlates (Mataix-Cols et al., 2004; Saxena et al., 2004), genetic susceptibility loci (Samuels et al., 2007) and poorer response to both cognitive-behavioral and pharmacological treatment (e.g., Abramowitz, Franklin, Schwartz & Furr, 2003; Saxena et al., 2002). In addition, hoarding symptoms are not more prevalent in patients with OCD than in patients with other anxiety disorders (Abramowitz, Wheaton, & Storch, 2008), or non-anxiety psychiatric disorders (Wu & Watson, 2005).

Accordingly, many authors have proposed that hoarding is not itself a symptom of OCD, but instead a separate phenomenon that co-occurs with true OCD symptoms in some patients (Abramowitz, Wheaton, & Storch, 2008; Wu & Watson, 2005). Further evidence for the separation of hoarding from OCD comes from prevalence estimates. Whereas OCD is estimated to be relatively rare (2.3% lifetime prevalence; Ruscio, Stein, Chiu & Kessler, 2010), preliminary evidence suggests that hoarding problems may be much more common in the population. For example, two studies reported hoarding prevalence rates of around 5% (Samuels et al., 2008; Mueller et al., 2009). As hoarding does not appear to fit within OCD, it is in need of its own diagnostic category.

Several proposals have attempted to define a "compulsive hoarding syndrome" (Saxena, 2007, 2008). However, it has been pointed out that the use of the term "compulsive" is misleading as it may suggest that hoarding is secondary to obsessive-compulsive disorder (Pertusa et al., 2010). In addition, whereas compulsive behaviors are typically repetitive,

stereotypic, and emotionally negative (e.g., distressing and frustrating), hoarding behaviors (i.e., acquiring and saving items) are usually emotionally neutral (or even positive) and not typically distressing. Emerging consensus has called for the creation of a new entity, "Hoarding Disorder" to be included in the upcoming revision to the diagnostic system (*DSM-5*), which would be included as either an independent anxiety disorder or as a part of the obsessive-compulsive spectrum of disorders if such a classification is made (Mataix-Cols et al., 2010). The diagnostic features of this condition, as recommended to the *DSM-5* committee (Mataix-Cols et al. 2010) are as follows: (a) persistent difficulty discarding personal possessions even of limited value, (b) accumulation of a large number of possessions that clutter the living/working area and prevent the normal use of the space and (c) the symptoms cause clinically significant distress or impairment in social, occupational or other functioning. Along with these criteria, a specifier ("with excessive acquisition") was included to reflect the fact that a subset of individuals with hoarding problems actively accrue new items (e.g., through yardsales) whereas others passively accumulate items without actively seeking them out (e.g., allowing junk mail to build up).

Importantly, in order to qualify as hoarding disorder, the symptoms mentioned above must not be secondary to any other mental disorder or general medical condition (i.e., primary or essential hoarding). This is an important caveat, as hoarding-like symptoms are noted in many other conditions (e.g., food hoarding in eating disorders; Frankenburg, 1984; accumulation of squalor in dementia; Hwang et al., 1998). Complicating matters, sometimes acquiring and failing to discard items are noted as symptoms of true OCD (Pertusa, Frost, & Mataix-Cols, 2010). For example, some OCD patients might hoard cleaning products and designate a cluttered area for "contaminated" objects and clothing; others avoid discarding

objects because of the fear of catastrophic consequences (e.g., "If I throw away something with a lucky number on it, something bad will happen"). In each of these cases, these collecting/difficulty discarding behaviors would not be counted as a primary hoarding problem given that they result directly from another disorder. To qualify as Hoarding Disorder, the behaviors must be independent from other conditions and proceed from their own antecedents. Currently, the field is in the exciting position of defining what constitutes this new and independent condition.

Model of Hoarding Disorder

At present, the best articulated model of hoarding disorder is the cognitive-behavioral approach (Frost & Hartl, 1996; Hartl & Frost, 1999; Steketee et al., 2000). This model suggests that pathological hoarding results from deficits or problems with (a) information processing, (b) problems in forming emotional attachments, (c) emotional distress and avoidance behaviors and (d) dysfunctional beliefs about possessions (Steketee & Frost, 2003). According to this model, individuals with hoarding problems become excessively emotionally attached to their possessions ("hypersentimentality"; Frost et al., 1995), often as a result of dysfunctional beliefs about possessions (e.g. "I am responsible for the wellbeing of this possession"; "Throwing this away would be like throwing away a part of me"; Steketee et al., 2003). As a result of this attachment, hoarders find it extremely difficult to discard items and usually avoid doing so.

The cognitive-behavioral model described above is currently being empirically evaluated and has shown promise (Steketee & Frost, 2003). However, this line of research remains in its nascent stages. Therefore, the present study sought to shed light on two important aspects of hoarding disorder: information processing and affective responses.

Information Processing in Hoarding Disorder

Current conceptualizations of hoarding implicate information processing deficits in the areas of attention, categorization, memory, and executive functioning (Frost & Hartl, 1996). These difficulties are thought to impair hoarders' ability to sort through their possessions and make decisions on which items to retain and which to discard. Individuals with hoarding problems have also been noted to have difficulty sustaining attention and motivation, which may result from impaired executive functioning (Grisham et al., 2007). A small number of studies have begun to examine neuropsychological functioning in hoarding in order to verify these hypothesized functioning deficits. For example, in one study, hoarding was associated with deficits in categorization and organization of information (Wincze, Steketee, & Frost, 2007). In that study, hoarders were found to have an under-inclusive categorization style, in which they set apart possessions based on their unique aspects rather than similarities. Another study found that hoarding participants had poorer memory recall and used less effective strategies for organizing information in two laboratory memory tests, compared to a healthy community control group (Hartl et al., 2004). In addition, decision-making problems have also been observed in hoarding participants, as evidenced by higher scores on self-report measures of indecisiveness and difficulty making decisions (Frost & Gross, 1993; Steketee, Frost, & Kyrios, 2003).

In the most thorough investigation of neuropsychological functioning in hoarding to-date, Grisham and colleagues (2007) compared individuals with significant hoarding problems to a mixed clinical comparison group (consisting of mixed mood and anxiety disorders) and a nonclinical community control group on measures of working memory, continuous performance, intelligence and attention. The results revealed that those with

hoarding problems had poorer nonverbal intelligence and sustained attention. Interestingly, the groups did not differ in terms of working memory or verbal intelligence. Another study reported that OCD patients with hoarding symptoms had significantly poorer performance than non-hoarding OCD patients on the Iowa Gambling Task (IGT; Bechara, Damasio, Damasio, & Anderson, 1994), indicating impaired decision making among the hoarding patients (Lawrence et al., 2006).

However, studies on this issue have not always consistently reported neuropsychological deficits in association with hoarding problems. For example, a second study found no difference between individuals with hoarding, non-hoarding OCD patients, and community controls on the Iowa Gambling Task (Grisham et al., 2007). In addition, studies to date have examined only certain aspects of information processing in hoarding, particularly attention, decision making and categorization. The construct of information processing is broad and subsumes multiple different categories of how information is perceived, encoded, stored and acted upon. More study is needed to determine which specific aspects within the information processing umbrella are impaired in hoarding disorder. Whereas most studies conducted on this topic to date have used either self-report measures or performance-based laboratory tests, investigations using additional methodologies could prove useful. In particular, psychophysiological methods have the benefit that they can tap into automatic processes without being influenced by motivation or desirability biases (Dawson, Schell, & Bohmelt, 1999). Therefore, in the present study we compared hoarding and non-hoarding individuals using a psychophysiological index of information processing that has been shown to be deficient in certain psychotic and internalizing disorders: prepulse inhibition (PPI) of the acoustic startle reflex (Braff & Geyer, 1990; Swerdlow et al., 2008).

The startle reflex is an automatic contraction of the muscles in response to sufficiently sudden and intense stimulation. Although this stimulation can occur in any modality (visual, auditory or tactile), laboratory studies of the human startle response have primarily measured the eyeblink component of the acoustic startle using electromyography (EMG) of the orbicularis oculi muscle following a loud acoustic pulse (Graham, 1975). PPI occurs when a relatively weak sound (i.e., the prepulse) precedes the startle-eliciting sound (i.e., the pulse) by 30-500ms and inhibits the startle response (Blumenthal, 1999). On trials with a prepulse, responding to the startle pulse is greatly reduced (often 55-100% lower in magnitude; Swerdlow, Geyer, & Braff, 2001; Braff, 2010). This reduced responding is seen across all mammalian species tested to date (Braff, 2010) and is believed to occur as a result of the brain being occupied by processing the prepulse when the startle occurs (Blumenthal, 1999). Reduced responding on trials with a prepulse has been hypothesized to "protect" the processing of the prepulse, allowing the maximal amount of information to be extracted from the prepulse, without being disrupted by the pulse (Blumenthal, Elden, & Flaten, 2004; Swerdlow et al., 2008). Deficits in PPI (i.e., large responses to the startle pulse) have therefore been seen as indicative of impaired information processing (Braff, 2010).

PPI has increasingly been used as an important measure in clinical science studies of psychopathology (Braff, 2010; Swerdlow et al., 2008). PPI deficits were first observed in patients with schizophrenia (Braff et al., 1978), but since that time low levels of PPI have been demonstrated in a range of disorders that also involve deficits in the processing of information, including panic disorder (Ludewig et al., 2002), Asperger's syndrome (McAlonan et al., 2002), and PTSD (Grillon et al., 1996). Importantly, two studies have also reported low PPI in patients diagnosed with OCD (Hoenig et al., 2005; Swerdlow et al.,

1993), although a recent report found no association between OCD and decreased PPI (de Leeuw et al., 2010). To date however, no investigation of PPI in relation to hoarding symptoms has been made.

Low levels of PPI have generally been interpreted as indicating problems with how information is processed (since the processing of the prepulse is interrupted by the full response to the startle-eliciting stimulus). For the past 30 years, the dominant conceptual account linking low PPI to psychological experience has involved the idea of deficient sensorimotor gating (Braff, 2010). These accounts suggest low PPI is indicative of gating deficits, involving problems with inhibiting sensory and motor responses (i.e., sensorimotor gating; Geyer & Braff, 1987; Braff & Geyer, 1990). For example, Swerdlow and colleagues (1992) suggested that in schizophrenia PPI deficits relate to difficulty suppressing (gating) irrelevant thoughts and sensory experiences (hallucinations and delusions), while in OCD gating problems might relate to difficulty inhibiting repetitive thoughts and behaviors (obsessions and compulsions). Sensorimotor gating thus appears to involve problems with inhibiting responses and appropriately filtering information. Similarly, hoarding symptoms have also been described in terms of inhibitory failure. Grisham et al. (2007) suggest that "difficulty suppressing responses evoked by the environment may contribute to excessive acquisition and saving behavior" (p. 1472). For example, some individuals may see an object an experience an urge to acquire it even if it is not needed. Failure to suppress this urge could result in maladaptive acquiring and saving. This conceptual account of hoarding problems provides initial reasoning to hypothesize a connection between low PPI (a purported marker of inhibitory failure) and hoarding problems, but as yet no investigation of PPI in relation to hoarding has been conducted.

Neurobiological evidence also supports the hypothesis that hoarding would be associated with low PPI, as neuroimaging studies have suggested that hoarding symptoms involve abnormalities in PPI-relevant brain areas. PPI is mediated by an area in the brainstem called the pedunculopontine tegmental nucleus (PPTg; Yeomans et al., 2006), which is regulated by complex interactions within and between forebrain, midbrain, and brainstem structures (Swerdlow et al., 2001; Winn, 2006, 2008). PPI deficits have been linked to increased activity in the limbic areas (such as the amygdala) and reduced activity in the frontal areas (e.g., prefrontal cortex and orbital cortex; Swerdlow et al., 2001). Importantly, hoarding has also been linked to activity in specific cortical areas, including the cingulate gyrus and orbitofrontal cortex (Mataix-Cols et al., 2004; Saxena et al., 2004). Therefore, in the present study we sought to use PPI as a tool to further investigate inhibitory gating deficits in relation to hoarding disorder. We also included measures of specific domains of information processing previously linked to hoarding symptoms (attention problems and impaired decision-making, as reviewed above) in order to determine how PPI might relate to these measures[1].

Affective Responses in Hoarding Disorder

Emotional processing is another understudied area of hoarding disorder, despite the fact that emotional distress is one of the core features of the cognitive-behavioral model of hoarding (Steketee & Frost, 2003). As detailed in case reports (Frost & Hartl, 1996), clinically significant hoarding problems are associated with problematic emotions of many valences. For example, many individuals with hoarding problems respond with intense anger when others touch, rearrange, or throw out their possessions (Greenberg, 1987). Hoarding is also associated with high levels of anxiety in anticipation of discarding situations, and in

laboratory studies hoarders also self-report more anxiety when sorting through possessions (Wincze et al., 2002). Finally, after throwing something away, many hoarders feel intense distress. For example, Frost and Hartl (1996) detail the case of a client who reported that she wanted to die after throwing away a prized possession as part of treatment. Thus, the core symptoms of hoarding disorder appear to involve strong negative emotions (Steketee & Frost, 2002).

Despite the importance of dysfunctional emotional processing in relation to hoarding symptoms, few studies have explicitly focused on this aspect of the disorder, and none have used psychophysiological methods. This is an important omission, as several aspects of these approaches, which are not subject to the many of the biases inherent in self-report, interview, and other question-based assessment techniques, make psychophysiological methods uniquely suited to elucidating emotional processes (Dawson, Schell, & Bohmelt, 1999). Startle techniques, in particular, have proven useful in this area, as described below.

The startle response is a defensive reflex, but is modulated by emotional state. Negative emotions tend to facilitate defensive reflexes, while positive emotions are not congruent with defensive responding and therefore tend to attenuate startle reflexes (Bradley, Cuthbert, & Lang, 1993; Lang, Bradley, & Cuthbert, 1998). Studies of affective valence startle modulation (AVSM) capitalize on these startle reflex differences in order to tap into emotional states. In the AVSM paradigm, startle stimuli are delivered in the presence of valenced stimuli (e.g., standardized pleasant, neutral, and unpleasant pictures). In healthy subjects, (i.e., those without psychopathology), startle blink response magnitudes are modulated in a linear pattern by picture valence: startle responses are largest in the presence

of negative pictures, moderate during presentation of neutral pictures, and smallest in the presence of pleasant pictures.

Interestingly, AVSM responses have been found to be different in individuals with various forms of psychopathology. For example, individuals with antisocial personality disorder do not show enhanced blink magnitudes when viewing unpleasant photographs compared to neutral images (Miranda, Meyerson, Myers, & Lovallo, 2003). In contrast, compared to control subjects without psychopathology, individuals with specific phobia appear to show even more enhanced startle during negative stimuli presentation, particularly when related to their phobic stimuli (e.g., fear-potentiated startle; Globisch, Hamm, Esteves, & Ohman, 1999; Hamm, Cuthbert, Globisch, & Vaitl, 1997). Individuals with GAD and PTSD do not show the general linear trend in valence modulation, but instead appear to have enhanced general responding regardless of emotional foreground (Vaidyanathan, Patrick, & Cuthbert, 2009; Ray et al., 2009; Lang, McTeague, & Cuthbert, 2007). AVSM has also been used to demonstrate disturbed emotional processing in autism (Dichter, Benning, Holtzclaw, & Bodfish, 2010).

As of yet, no study has investigated startle responses in relation to hoarding problems. Therefore, in the present study we included an AVSM block in order to compare individuals with hoarding problems to community controls. In addition to the standardized pleasant, neutral and unpleasant foreground stimuli commonly used in other studies (e.g., Dichter et al., 2010), we also include images directly relevant to hoarding symptoms. These pictures depicted images of cluttered rooms in order to elucidate whether hoarders and non-hoarders have different emotional responses to such scenes. Whereas we expected images of clutter to be negative emotional stimuli for individuals without hoarding problems, how hoarders

would emotionally respond to such images was unclear. Steketee and Frost (2003) posited that seeing clutter might serve as a "safety signal" to individuals with hoarding problems, and emotions of relief/satisfaction have been commonly reported in connection to hoarding symptoms (e.g., Frost & Gross, 1993; Seedat & Stein, 2002). However, a case series of individuals with hoarding problems found that emotions related to guilt and shame/embarrassment were also commonly reported in relation to hoarding symptoms (Seedat & Stein, 2002). We expected that for the control group, startle responses would be potentiated during presentation of clutter images (relative to neutral images) but that this effect will not be observed in the hoarding group, indicating that clutter does not induce negative affect in the hoarding group to the same degree.

In addition to changes in patterns of affective modulation, startle studies have also demonstrated increases in baseline startle reactivity in some disorders, such as generalized anxiety disorder (GAD; Ray et al., 2009), PTSD (Butler et al., 1990; Morgan et al., 1995) and OCD (Kumari et al., 2001; Buhlman, et al., 2007). Some studies have also measured startle responses after using laboratory exercises to provoke symptoms, such as induced worry in GAD (Ray et al., 2009), and confrontation with trauma-relevant images and sounds in PTSD (Miller & Litz, 2004). Therefore, we also extended this type of study to hoarding. Specifically, we devised a laboratory paradigm designed to serve as a symptom provocation specific to hoarding: discarding a possession. Difficulty discarding items is a core feature of hoarding disorder. In order to simulate this symptom under controlled laboratory conditions we presented participants with an object (a postcard depicting images of flowers) and asked them to consider it as their own belonging. We chose a postcard because it was aesthetically pleasing and functional, two important reasons often given by hoarders for saving items

(Frost & Steketee, 2010). Although the objects collected by individuals with hoarding problems are highly idiosyncratic, paper items are the most commonly hoarded object (Frost & Steketee, 2010). Empirical research has linked hoarding problems to strong initial attachment to objects, including items of limited monetary value (e.g., a novelty keychain; Grisham et al., 2009). Therefore, even though participants in our study only possessed the postcard for a short time, we believed that the discarding task would still be distressing and would therefore serve as a valid proxy for discarding symptoms. In order to ensure the validity of this paradigm, we also included self-reported ratings of emotional upset (e.g., anxiety, sadness) as described below.

Given findings that a range of anxiety disorders have been associated with increased baseline startle reactivity (see McTeague et al., 2009), we hypothesized that individuals with hoarding problems would show increased baseline responses relative to controls. Further, we hypothesized that this between-group difference would be exacerbated by the discarding task, as individuals with hoarding find discarding possessions very difficult, even in contrived laboratory situations (An et al., 2009). We also considered the possibility that discarding the postcard might only be effective at provoking distress for a subgroup of individuals in our hoarding group. In particular, we considered that this task might be more effective in individuals meeting criteria for hoarding disorder with excessive acquisition, as excessive acquisition has been linked to strong initial attachments to objects (Grisham et al., 2009).

The results of these startle blocks could have several important implications for advancing knowledge about hoarding disorder. AVSM studies can be used to index underlying neurobiological processes, as modulation of the startle reflex relates to the priming of appetitive and defensive systems that are neurobiologically-based (Davis, 1989).

For example, whereas decreased startle is associated with the nucleus accumbens, increased startle is associated with activity of the central nucleus of the amygdala and the bed nucleus of the stria terminalis (Koch & Fendt, 2003). In addition to revealing its underlying neurobiological correlates, investigation of emotional responses may help to determine where to classify hoarding disorder. Current proposals suggest that hoarding disorder should be either an anxiety disorder or part of the "obsessive-compulsive spectrum" if such a classification is included in *DSM-5* (Mataix-Cols et al., 2010). However, other approaches to classifying mental disorders have focused on patterns of comorbidity between mood and anxiety disorders and suggest an alternate model in which existing diagnoses are re-sorted into "distress" and "fear" disorders (e.g., Sellbom et al., 2008; Watson et al., 2005). To date however, no investigation to address where hoarding belongs in this re-conceptualization has been made. A recent review suggested that AVSM studies differentiate between these two major classes of disorders and therefore may help in this new classification (Vaidyanathan, Patrick, & Cuthbert, 2009). Specifically, distress based-conditions (e.g., PTSD, generalized anxiety disorder) are associated with a pattern of elevated startle responses across all valence categories, while fear-based conditions (e.g., phobias) are associated with elevated startle responses only during negatively valenced stimuli (e.g., fear-potentiated startle). Therefore, the pattern of responses observed in the present study could help determine which class of disorder (fear or distress) hoarding most resembles.

General Overview

To summarize, we conducted an investigation into two aspects of hoarding disorder (information processing and affective responses) using methodologies based on acoustic startle responses: general startle reactivity (at baseline and after discarding), PPI, and AVSM.

Many existing studies on hoarding have been conducted in samples of patients with OCD. These studies have primarily involved comparing patients meeting diagnostic criteria for OCD who also experience hoarding symptoms to OCD patients without hoarding symptoms (e.g., Saxena et al., 2004, Samuels et al., 2002; Samuels et al., 2007; Wheaton et al., 2007). A limitation of these studies is that it is difficult to disentangle the correlates of hoarding and OCD. In order to get around this problem, recent studies have recruited independent samples of hoarding participants (e.g., Grisham et al., 2007; Wincze et al., 2007). Therefore, as in those investigations, we recruited individuals with primary hoarding problems. Comparison participants were drawn from the community and matched to the hoarding group on demographic variables (gender, age, ethnicity). After recruitment, participants were invited to a single-session laboratory experiment. In the first part of the study, participants' hoarding symptoms and comorbid diagnoses were assessed by a combination of interview-based and self-report measures (described below). In the second part of the study, we affixed electrodes and recorded four blocks of startle responses: 1) habituation, 2) PPI, 3) AVSM, and 4) at baseline and immediately following discarding.

Hypothesis 1: PPI Responses. On the basis of impaired information processing in the cognitive-behavioral model of hoarding disorder, we hypothesized that the hoarding group would demonstrate significantly lower PPI than the control group.

Hypothesis 2: AVSM Responses. On the basis of previous research, we expected that the control group would show a linear pattern of increasing startle modulation in relation to the affective picture categories (pleasant, neutral and unpleasant). However, we hypothesized that this pattern would not emerge in the hoarding group, who we hypothesized would show increased startle reactivity across conditions. In addition, in comparison to neutral images,

we hypothesized that images of clutter would potentiate startle responses in the control group but not in the hoarding group, indicating that seeing clutter does not engender negative affect in hoarders to the same degree as in non-hoarders.

Hypothesis 3: Baseline/Discarding Responses. We hypothesized that the hoarding group would demonstrate higher baseline startle responses compared to the control group, and that this between group-difference would be exacerbated following the discarding task.

Methods

Participants

We recruited 34 participants meeting criteria for hoarding disorder (Mataix-Cols et al., 2010), as assessed by a trained interviewer using a clinical interview and confirmed via validated self report measures. As part of the proposed criteria for hoarding disorder, the hoarding symptoms were primary (i.e., not secondary to another condition). Therefore, participants suffering from hoarding symptoms secondary to OCD or any other disorder were not eligible for the study. However, hoarding participants were not excluded on the basis of comorbid diagnosis of a mood or anxiety disorder, though one participant in the hoarding group was screened out of the study due to active psychotic symptoms. By allowing participants with these secondary comorbid diagnoses to participate, we aimed to increase the generalizability of our results to the broader population of individuals with hoarding problems in the community, given that up 60% of these individuals meet criteria for a least one other condition (Grisham et al., 2007; Frost, Steketee, Tolin, & Brown, 2006). In our sample, 13 of 33 in the hoarding group had a current comorbid diagnosis. Eight of those individuals had one additional diagnosis, two had two additional, two had three additional, and one individual had five additional diagnoses. The total number of specific additional

diagnoses was: 8 GAD, 5 dysthymia, 2 OCD, 2 major depressive disorder, 1 PTSD, 1 bipolar disorder, 1 social phobia, and 1 substance/alcohol dependence. Hoarding participants were recruited via community-wide emails, postings on local websites (craigslist) and flyers posted in the community.

Control participants were 30 individuals selected in order to match the composition of the hoarding group on demographic variables including age, ethnicity and gender composition. Control participants were screened to ensure that they did not meet criteria for hoarding disorder, or any current Axis I pathology. Control participants were recruited from the general community using the campus-wide email system and postings on craigslist. All participants were compensated with $30 for their participation.

Interviewer-based Measures

Structured Interview for Hoarding Disorder (SIHD; Pertusa & Mataix-Cols, 2011). The SIHD is a semi-structured interview based on the provisional diagnostic criteria for hoarding disorder as recommended for publication in *DSM-5* (Mataix-Cols et al., 2010). Individual items are provided to assess each criterion (A-F), and a differential diagnosis item is included to ensure that the hoarding symptoms are not better explained by OCD or any other mental/physical disorder. Specifiers are included to rate the individual's level of insight (good, poor, absent) as well as the presence of excessive acquisition (Pertusa & Mataix-Cols, 2011).

Hoarding Rating Scale-Interview (HRS-I; Tolin, Frost, & Steketee, 2010). The HRS-I is a brief, 5-item semi-structured interview that measures the core symptoms of hoarding (difficulty discarding, clutter, excessive acquisition, distress and impairment). The HRS-I has demonstrated excellent internal consistency and test-retest reliability in clinical

samples (Tolin, Frost, & Steketee, 2010). It also differentiates between hoarding and non-hoarding individuals and converges well with other measures of hoarding severity (Tolin, Frost, & Steketee, 2010). Tolin and colleagues (2008) established a score of 14 as an optimal cutoff value for identifying individuals with a clinically significant hoarding problem.

Mini International Neuropsychiatric Interview (MINI; Sheehan et al., 1998). The MINI is a brief, structured diagnostic interview that assesses a selection of psychiatric diagnoses according to the current diagnostic criteria (*DSM-IV-TR*; APA, 2000). The MINI has shown high interrater reliability and test-retest reliability (Sheehan et al., 1998). In the present study, the MINI was used to establish diagnostic comorbidity and to rule out participants with current mania and psychosis (exclusionary criteria for the present study).

Self-Report Measures

Saving Inventory-Revised (SI-R; Frost, Steketee, & Grisham, 2004). The SI-R is a 23-item questionnaire designed to measure hoarding symptoms, including difficulty discarding, acquisition, and clutter. It has been found to be a valid measure of hoarding behaviors in both clinical and non-clinical populations (Coles et al., 2003; Frost, et al., 2004). The SI-R has been found to have good test–retest reliability and strong internal consistency (Frost et al., 2004).

Saving Cognitions Inventory (SCI; Steketee, Frost, & Kyrios, 2003). The SCI is a 24-item self report measure that assesses beliefs related to possessions. Respondents are asked to rate the presence of specific cognitions when deciding whether to discard a possession on a seven-point likert-type scale (e.g. "Throwing away this possession is like throwing away a part of me"). Items were generated based on the theoretical model of Frost and Hartl (1996). Steketee and colleagues (2003) found support for the use of an SCI total

score and four subscale scores (Emotional attachment, Memory, Control, and Responsibility toward possessions). The SCI total has been found to be a valid measure of hoarding beliefs with good internal consistency in clinical samples (Steketee, et al., 2003).

Clutter Image Rating Scale (CIR; Frost, Steketee, Tolin, & Renaud, 2008). The CIR is a pictorial measure of clutter severity that was included in the present study in order to confirm the extent of the hoarding group's problematic clutter. The scale prompts respondents to rate the clutter in three rooms of their home: the kitchen, living room, and bedroom. For each room the scale presents participants with nine photographs of the room in increasing clutter. Participants select the photograph that most resembles the level of clutter in each room of their home. The CIR possess strong internal consistency and test-retest reliability (Frost, Tolin, & Renaud, 2008; Tolin, Frost, & Steketee, 2010). Importantly, participants ratings of their own homes correlate well with observer ratings (inter-rater reliability), and the CIR converges well with other measures of hoarding severity (Frost, Steketee, Tolin, & Renaud, 2008). Tolin and colleagues (2008) established that a score of 4 or greater indicates clinically significant clutter.

Depression Anxiety Stress Scales 21 (DASS-21; Antony et al., 1998). The DASS-21 is a short form of the original 42-item DASS (Lovibond & Lovibond, 1995). The scales comprise three separate subscales, measuring self-reported depression, anxiety, and stress on a 0-4 scale. The DASS-21 subscales have been found to have good reliability and construct validity in clinical samples (Page, Hooke, & Morrison, 2007).

Dimensional Obsessive-Compulsive Scale (DOCS; Abramowitz et al., 2010). The DOCS is a 20-item self-report measure that assesses the severity of the four most consistently replicated OCD symptom dimensions (which correspond to four DOCS subscales): (a)

contamination, (b) responsibility for harm and mistakes, (c) symmetry/ordering, and (d) unacceptable thoughts. To accommodate the heterogeneity of OCD symptoms, and the presence of obsessions and rituals within each symptom dimension, each subscale begins with a description of the symptom dimension along with examples of representative obsessions and rituals. The examples clarify the form and function of each dimension's fundamental obsessional fears, compulsive rituals, and avoidance behaviors. Within each symptom dimension, five items (rated 0 to 4) assess the following parameters of severity (over the past month): (a) time occupied by obsessions and rituals, (b) avoidance behavior, (c) associated distress, (d) functional interference, and (e) difficulty disregarding the obsessions and refraining from the compulsions. The DOCS subscales have excellent reliability in clinical samples and nonclinical samples (α = .94-.96), and the measure converges well with other measures of OC symptoms (Abramowitz et al., 2010).

Attention Deficit/Hyperactivity Disorder Symptoms Scale (ADHDSS; Barkley & Murphy, 1998): The ADHDSS symptoms scale is an 18-item self-report checklist of inattention and hyperactivity symptoms. Participants first respond [on a scale from '0' (never or rarely) to '3' (very often] in reference to their behaviors as a child (5–12 years old) and then in reference to the past six months. Only scores for the last six months were used in the present study. The ADHDSS has been used in previous investigations of inattention symptoms in hoarding populations (Hartl et al., 2005; Tolin & Villavicencio, 2011) and has demonstrated good reliability and construct validity (Barkley et al., 2002).

Frost Indecisiveness Scale (FIS; Frost & Shows, 1993). The FIS is a 15-item scale measuring difficulties with decision-making and comprises two subscales: (1) Fears about Decision-Making consisting of nine items, and (2) Positive Attitudes towards Decision-

Making consisting of six items. A total score is computed by reverse scoring the Positive Attitudes towards Decision-Making subscale and summing the two subscales. The FIS has demonstrated good reliability and validity (Frost & Shows, 1993) and has previously been used in studies of hoarding (Steketee, Frost, & Kyrios, 2003).

Startle Reactivity.

All acoustic probe stimuli were generated by Adobe Audition, presented by SuperLab, and delivered to the participants through Sennheiser PX200 headphones. Startle reactivity was quantified as eyeblink (electromyographic) EMG responses and measured from the orbicularis oculi muscle with two In Vivo Metric surface recording electrodes (Ag/AgCl, 11mm outer diameter, 4mm inner diameter contact surface) placed below the left eye. A third electrode was placed on the temple as a ground. EMG activity was amplified with a Biopac EMG amplifier and sampled (1000Hz) by a Biopac MP150 workstation which stored four versions of the EMG input: raw unfiltered EMG, filtered EMG in a passband of 28-500Hz, a rectification of the filtered EMG signal, and a rectified and smoothed (five sample boxcar filter) derivation of the filtered signal. The analyzed data were based on the smoothed EMG signal.

Procedure

Telephone Screening. Participants who were interested in the study were briefly screened via the telephone in order to explain the study requirements and determine their initial eligibility. Individuals who appeared to be appropriate for the study were scheduled for the laboratory session and mailed a packet of the self-report questionnaires to complete prior to their appointment.

Diagnostic Interviews. Upon arrival at the laboratory, a trained research assistant reviewed the informed consent form with participants. After consenting to participate in the study, the three interview-based measures were completed (MINI, SIHD, HRS-I). To be diagnosed with hoarding disorder, participants fulfilled the diagnostic criteria of the SIHD and meet established cutoff scores on the HRS-I, CIR and SI-R. Immediately following the interview, participants were given a postcard that was used in the discarding-task (described below).

Psychophysiology Session. Startle responses were recorded in accord with current recommendations (Blumenthal et al., 2005). Specifically, participants were seated individually in a sound-attenuated room, and two surface recording electrodes filled with Synapse conducting paste were then attached; one to the skin overlaying the orbicularis oculi muscle directly below the lower eyelid, and the other approximately 15mm (center to center) lateral to and slightly higher than the first electrode. A ground electrode was placed on the skin overlaying the left temple. Headphones were then comfortably placed on the participant (see Blumenthal et al., 2004 for similar setup methods). Following standard procedure, the first block of trials was a habituation block consisting of 15 trials of 100dB auditory stimuli presented at intervals of 13 to 23secs. These trials were included to account for the natural habituation of the startle response that could distort the data if they occurred during the experiment. After the administration of 15 trials, startle habituation reaches an asymptote (Lane, Franklin, & Curran, 2011). This block lasted approximately ten minutes. After the habituation block, three experimental blocks were administered: PPI, AVSM and pre/post discarding.

PPI Block. PPI was assessed following the recommendations of Franklin et al. (2007). Specifically, background noise (70 dB(A)) was turned on, and then participants were administered 20 trials containing a 100dB(A) startle stimulus. Of the 20 trials, 10 consisted of only the 100dB(A) stimuli (startle alone trials), while 10 trials also contained an 85dB(A) prepulse (i.e. PPI trials) that was presented 120 msec before the startling stimulus. Trials were presented in one of two pseudo random orders with intertrial intervals between 10 and 30 seconds. This block took approximately 10 minutes.

AVSM Block. In the AVSM block, startle stimuli were presented while participants viewed pictures of varying emotional valence (positive, negative, neutral and clutter). Positive, negative, and neutral images were chosen from the International Affective Picture System (IAPS; Lang, Bradley, & Cuthbert, 2005) on the basis of their published affective valence and arousal ratings. We selected pleasant, neutral, and unpleasant images that have been established in previous AVSM studies (Dichter, Tomarken, Shelton, & Sutton, 2004). Hoarding-specific images of clutter were drawn from the pool of images used to create the Clutter Image Rating (CIR) and created in-house for the present study. Following procedures used elsewhere (Dichter et al., 2010), the AVSM block began with five neutral images presented with startle probes in order to ensure that startle responses had habituated and to orient participants to viewing images (these trials were not included in analyses). Subsequently, 11 images from each category were presented in one of two randomly ordered sequences. To reduce predictability, startle stimuli only accompanied 9 of the 11 pictures in each category, as in previous studies (Dichter et al., 2010). This block lasted approximately 22 minutes.

Discarding Block. In the discarding block, we measured participants' startle responses immediately before and after undergoing a disorder-specific stressor: discarding a possession. As mentioned previously, during the initial interview portion of the experiment, participants were given a postcard with the instruction that they should consider it as their own belonging. Participants were asks to rate how much they liked their postcard on a 10-point likert scale (1-do not like it at all, 5-moderately like it, and 10 really like it). Previous research suggests that hoarding problems are associated with strong initial attachment to objects (Grisham et al., 2009), lending credence to our paradigm. In the discarding task, participants were asked to discard the postcard into a paper shredder. This task mirrors other symptom-provocations used in studies on hoarding (An et al., 2009). Prior to the discarding task, 10 startle stimuli were presented as a baseline measure of reactivity. Following the discarding task another block of 10 startle stimuli was presented. Both blocks lasted approximately four minutes. In addition, immediately following the discarding task, participants were asked to make subjective ratings of several different emotions (distress, anxiety, sadness and anger/frustration) each on a 10 point Likert-type scale.

Subjective Stimuli Rating. As in previous AVSM studies (Dichter et al., 2010), participants were asked to rate the valence and arousal of each of the images used in the AVSM block using a 9-point Likert-type scale. For ratings of valence responses ranged from -4 (extremely unpleasant) to +4 (extremely pleasant). Arousal ratings ranged from 0 (not at all arousing) to 8 (extremely arousing). Responses were collected using Qualtrics, an online web survey development tool. This task lasted approximately ten minutes. After completing this task, participants were debriefed, compensated ($30), and allowed to leave.

Data Analytic Plan

Scoring EMG responses. Blink response magnitudes were calculated for each stimulus condition according to best practices (Blumenthal et al., 2005). Response magnitudes were the average of the difference between peak and onset voltage of the smoothed EMG. Scorable responses were considered those that occurred within a window of 20–150 ms after stimulus onset. Trials on which a response cannot be detected were assigned a value of 0 whereas trials with invalid responses (such as EMG noise contamination or yawning) were scored as "missing." Approximately 5% of trials were lost due to being unscorable. In addition, for one participant in the hoarding group and two in the control group, computer errors caused responses to not be recorded during the AVSM and baseline and post-discarding blocks.

PPI Analyses. PPI was calculated as the proportion of the difference from control (i.e. [prepulse condition − control condition]/control condition) for response magnitude, as recommended by Blumenthal et al. (2004). Preliminary scoring revealed that three control and two hoarding participants demonstrated increased responding on the PPI trials. These responses likely originated from the scoring of spontaneous blinks during PPI trials, so these cases were excluded from subsequent analyses. To test the hypothesis that individuals in the hoarding group would have lower PPI scores compared to the control group, we compared the two groups' percent PPI scores by way of independent samples t-tests. We also sought to determine the effect of psychiatric comorbidity on PPI scores. We split the hoarding group into patients who were experiencing another current DSM-IV condition (Hoarding-comorbid group) and those who were not (pure hoarding group). We compared the two hoarding groups and the control group by way of a one-way ANOVA.

AVSM Analyses. The primary analysis of startle magnitude data from the AVSM trials was a Group X Valence repeated measures ANOVA with Group (hoarding, control) as the between-participants factor and picture valence (unpleasant, neutral, pleasant) as the within-participants factor. For the AVSM analyses, magnitude measures were averaged across the valence factor for each participant in order to create within participants T-scores as in other AVSM studies (e.g., Dichter et al., 2010). We expected to see a linear pattern of startle modulation (as tested with a first order polynomial contrast) in the control group but not in the hoarding group. Given the exploratory nature of analyses using the hoarding specific images, these trials were analyzed separately in comparison to neutral images by way of a 2X2 repeated measures ANOVA. Given the exploratory nature of these analyses we set an alpha level of .05.

Discarding Block. We hypothesized that the hoarding group would demonstrate greater baseline startle reactivity than the control group, and that the discarding task would increase startle reactivity in the hoarding participants more so than in the control participants. To test this hypothesis, we conducted a Group (hoarding versus control) by Block (baseline versus post-discarding) repeated measures ANOVA. As mentioned previously, we considered the possibility that this contrived laboratory stressor would only be effective at inducing stress in some hoarding participants. Therefore, we also sought to compare the results for hoarders with and without excessive acquisition, as we expected those with acquisition problems would respond more negatively to the postcard task.

Results

Preliminary Analyses

Table 1 presents the demographic and clinical characteristics for the present study. As can be seen, the hoarding and control groups did not differ in terms of age, $t = 1.56$, $p > .12$ gender, $\chi^2 = 0.29$, $p > .39$ or ethnic composition, $\chi^2 = 4.87$, $p > .30$. As would be expected, the hoarding group scored significantly higher than the control group on all measures related to hoarding symptoms, including the HRS-I, $t = 35.56$, $p < .001$, SI-R, $t = 23.27$, $p < .001$, SCI, $t = 14.34$, $p < .001$, and CIR, $t = 13.82$, $p < .001$. The hoarding group also scored significantly higher on symptoms of depression, anxiety, and stress as assessed by the DASS-21(range in $t = 2.88$-4.78, p's $< .01$) and OCD symptoms as assessed by the DOCS, $t = 5.12$, $p < .001$. As in previous studies, the hoarding group also demonstrated higher scores on the IS ($t = 5.58$, $p < .001$), and both the Inattention ($t = 4.41$, $p < .001$) and Hyperactivity ($t = 2.44$, $p = .03$) subscales of the ADHDSS.

PPI Results

The mean level of percent PPI observed in our sample as a whole was (mean ± standard error of the mean) = 77.26% (± 2.03), which is highly similar to mean PPI levels reported in other studies using the same parameters (e.g., 74.3%; Franklin et al., 2007). An independent samples *t*-test revealed no mean difference in PPI scores by group [hoarding patients=77.75%, ± 2.87, healthy controls = 76.68% ± 2.9], $t = 0.26$, $p = .80$, as demonstrated in *Figure 1*.

We next considered the effect of comorbidity in the hoarding group by comparing hoarding participants without other current pathology (pure hoarding patients), those with other current disorders (comorbid hoarding patients) and healthy controls, on mean level of percent PPI, by way of a one-way ANOVA. The means for these groups were as follows: pure hoarding patients = 79.62%, ± 3.74, comorbid hoarding patients = 74.79%, ± 4.51,

healthy controls = 76.68% ± 2.9, as presented in *Figure 2*. Group means did not significantly differ, $F(2, 56) = 0.39$, $p = .68$.

Nine of the hoarding participants reported current use of psychiatric mediations. To examine the effect of medication use on PPI, we compared these patients to the unmedicated hoarding participants. These groups did not significantly differ on percent PPI [unmedicated hoarding patients=77.4%, ± 3.53, medicated patients = 78.76 % ± 4.84], $t = 0.84$, $p = .84$.

Examination of the zero-order associations between PPI and the other study measures did not reveal any significant correlations between PPI and the HRS-I, SI-R, DOCS, CIR, SIR, or DASS-21 (range in *r*'s= -.17-+.07, all *p*'s >.1). Additionally, PPI scores were not significantly correlated with the IS or the ADHDSS subscales (range in r's= .003-.15, *p*'s>.36). We also investigated correlations in the control and hoarding group separately. In the hoarding group, PPI scores were not correlated with any of the study measures (all *p*'s>.1). In the control group, PPI scores were negatively correlated with the DASS-Anxiety subscale at a trend level ($r=-.3$, $p=.08$).

AVSM Block

Table 2 presents means and standard deviations for self-reported ratings of valence and arousal for all images presented during this block. A Group (hoarding, control) X Valence (Pleasant, Neutral, Unpleasant) 2X3 repeated measures ANOVA found no group differences in pleasantness ratings, $F(1, 60) = 0.46$, $p=.5$, and no significant interaction between Group and Valence, $F(2, 60)=0.16$, $p=.88$. There was a main effect of Valence, $F(2, 60)=696.25$, $p<.001$, and a significant linear Valence trend, $F(2, 55)=1,185.3$, $p<.001$, with pleasantness ratings decreasing linearly across the pleasant, neutral, and unpleasant categories, as demonstrated in *Figure 3*. Similar analysis of arousal data revealed a

significant effect of Group, $F(1, 60)=4.85$, $p=.03$, with the hoarding group rating the pictures as significantly more arousing on average. There was a significant effect of Valence, $F(2, 60)=76.85$, $p<.001$, but no significant Valence X Group interaction, $F(2, 60)=1.25$, $p=.29$. There was a significant quadratic Valence trend, $F(1, 60)=174.52$, $p<.01$, as depicted in *Figure 4*.

Figure 5 presents average startle responses for the three conditions (pleasant, neutral and unpleasant) by group, using within subjects T scores. The Group (Hoarding, Control) by Valence (Pleasant, Neutral, Unpleasant) 2X3 ANOVA revealed a main effect of Valence, $F(2, 58)=4.08$, $p=.02$, but no effect of Group, $F(1, 59)=0.0$, $p>.99$ and no significant Group X Valence interaction, $F(2, 59)=0.48$, $p=.62$. The overall linear Valence trend was significant, $F(1, 59)=8.24$, $p<.01$. We next expanded this analysis to consider the effect of comorbid disorders by conducting a 2X3 repeated measures ANOVA in which the grouping variable was expanded to include three groups (pure hoarding, comorbid hoarding, and control). Means from this analysis are presented in *Figure 6*. There remained a main effect of Valence, $F(2, 57)=4.78$, $p=.01$, with a significant linear Valence trend, $F(1, 58)=9.64$, $p<.01$. There was no effect of Group, $F(2, 58)=0.0$, $p>.99$ and no significant Group X Valence interaction, $F(4, 58)=0.57$, $p=.68$.

Clutter Images

We first compared subjective ratings of the clutter images. A Group (hoarding, control) X Valence (Neutral, Clutter) 2X2 repeated measures ANOVA revealed no group differences in pleasantness ratings, $F(1, 60) =0.48$, $p=.49$, and no significant interaction between Group and Valence, $F(1, 60)=0.53$, $p=.53$. There was a main effect of Valence, $F(1, 60)=174.91$, $p<.001$, indicating that both groups found the clutter images to be less pleasant

than the neutral images (clutter M=-2.33, SD=0.92, neutral M=-.40, SD=1.01). A similar 2X2 ANOVA comparing arousal ratings across groups resulted in a main effect of Group, $F(1, 60) = 10.14$, $p < .01$, a main effect of Valence, $F(1, 60) = 117.08$, $p < .001$, but no significant Group X Valence interaction, $F(1, 60) = 0.01$, $p = .93$. Specifically, both groups rated the clutter images (M=3.73, SD=2.47) as more arousing than the neutral images (M=1.79, SD=1.37) and on average the hoarding group rated both categories as being more arousing (hoarding M=3.40, SD=1.64, control M=2.08, SD=1.64).

We next compared average startle responses for the clutter and neutral image categories (within person T-scores computed across all four valence categories) by way of a Group (hoarding, control) X Valence (Neutral, Clutter) 2X2 repeated measures ANOVA. There was no main effect of Group, $F(1, 59) = .0$, $p = .99$, nor Valence, $F(1, 59) = 1.44$, $p = .24$, and no significant Group X Valence interaction, $F(1, 59) = 0.89$, $p = .35$, as depicted in *Figure 7*. As in previous analyses, we next expanded the group variable to account for comorbidity in the hoarding group and conducted a Group (pure hoarding, comorbid hoarding, and control) X Valence (Neutral, Clutter) 2X3 repeated measures ANOVA as displayed in *Figure 8*. There was no main effect of Group, $F(2, 58) = .03$, $p = .98$, nor Valence, $F(1, 58) = 1.53$, $p = .22$, and no significant Group X Valence interaction, $F(2, 58) = 2.32$, $p = .11$.

We expanded on these analyses by comparing average startle responses to the clutter images to those of unpleasant valence. We first conducted a Group (hoarding, control) X Valence (Unpleasant, Clutter) 2X2 repeated measures ANOVA. There was no main effect of Group, $F(1, 59) = .01$, $p = .93$, and no significant Group X Valence interaction, $F(1, 59) = 1.07$, $p = .34$. However, there was a main effect of Valence, $F(1, 59) = 15.35$, $p < .001$, with both groups having larger startle in the Unpleasant category. We expanded this analysis to

examine comorbidity by way of a Group (pure hoarding, comorbid hoarding, and control) X Valence (Unpleasant, Clutter) 2X3 repeated measures ANOVA. There was no main effect of Group, $F(2, 58) = 1.75$, $p = .18$, and no significant Group X Valence interaction, $F(2, 58) = 0.71$, $p = .5$. However, the effect of Valence remained significant, $F(1, 58) = 16.07$, $p < .001$, with all three groups demonstrating larger startle in the Unpleasant category.

Baseline and Post Discarding

There was no group difference in ratings of how much the postcard was liked, with both groups highly liking the postcard (hoarding patient M=7.67, SD=2.18, control M=8.0, SD=1.70, $t=-0.67$, $p=.51$). Immediately following instructions to shred the postcard, the experimenter asked participants to rate the severity of five emotions on a 10 point likert scale (1-not at all to 10-extreme). Participants in the hoarding group endorsed significantly more feelings of anxiety (hoarding patient M=2.55, SD=2.42, control M=1.17, SD=0.53, $t=3.18$, $p<.01$), sadness (hoarding patient M=3.36, SD=2.68, control M=1.67, SD=0.46, $t=4.64$, $p<.001$), guilt (hoarding patient M=3.33, SD=3.01, control M=1.2, SD=0.41, $t=4.04$, $p<.001$), anger (hoarding patient M=1.88, SD=2.0, control M=1.03, SD=0.18, $t=2.42$, $p=.02$), and general distress (hoarding patient M=3.64, SD=2.64, control M=1.17, SD=0.59, $t=5.22$, $p<.001$).

Group mean startle reactivity for the baseline and post-discarding blocks were calculated. Log transformations were performed in order to reduce skewness and heteroscedasticity. Data were analyzed with a repeated measures 2X2 ANOVA with one within factor (baseline vs. post-discarding) and one between factor (hoarding group status). Means startle responses are presented in *Figure 9*. There was a significant effect of group, $F(1, 58)=12.67$, $p<.001$, with the hoarding group having higher startle responses on average.

There was also a significant effect of block, $F(1, 58)=5.41$, $p<.03$, with startle responses lower in the post-discarding block compared to the baseline block. There was not a significant interaction between group and block, $F(1, 58)=0.12$, $p=.75$. In order to control for group differences in depression, anxiety and stress, we ran a similar 2X2 ANCOVA controlling for the three DASS-21 subscales. Group membership remained significant in the model, $F(1, 55)=7.68$, $p<.01$, whereas the effect of block was not, $F(1, 55)=1.71$, $p=.2$. There was also no significant interaction between block and group, $F(1, 55)=0.4$, p=.53. The DASS-21 Anxiety subscale was a significant covariate, $F(1, 55)=4.11$, $p<.05$. The Stress subscale approached significance, $F(1, 55)=3.63$, $p=.06$, while the Depression subscale was not significant $F(1, 55)=0.11$, $p=.74$,

We next considered the effect of comorbid disorders by conducting a 2X3 repeated measures ANOVA in which the grouping variable was expanded to include three groups (pure hoarding, comorbid hoarding, and control). Means from this analysis are presented in *Figure 10*. There was a significant effect of group, $F(2, 57)=6.25$, $p<.01$. Tukey's Honestly Significant Difference (HSD) post hoc testing revealed that the control group had smaller mean startle responses compared to both the pure hoarding and comorbid hoarding groups (p's=.01). The two hoarding groups (pure and comorbid) did not significantly differ ($p=.98$). There was also a significant effect of block, $F(1, 57)=5.11$, $p<.03$, with startle responses lower in the post-discarding block compared to the baseline block. There was not a significant interaction between group and block, $F(2, 58)=0.25$, $p=.78$. As before, we expanded this analysis in order to control for group differences in depression, anxiety and stress by conducting a 2X3 ANCOVA in which we entered the DASS-21 subscales as covariates. In this analysis, there remained a significant main effect of group $F(2, 54)=3.78$,

p<.001. With covariates in the analysis, the effect of block was not significant, F(1, 54)=1.22, p=.28. There was also no significant block X group interaction, F(2, 55)=0.26, p=.77. The DASS-21 Anxiety subscale was a significant covariate, F(1, 55)=4.02, p=.05. The Stress subscale approached significance, F(1, 54)=3.55, p=.07, while the Depression subscale was not significant F(1, 54)=0.12, p=.73.

We next considered the possibility that the postcard task may have been differently experienced by different individuals in the hoarding group. We ran a series of analyses to compare individuals with hoarding disorder and excessive acquisition (N=12) to those with hoarding disorder without this feature (N=21) and controls. A one way ANOVA revealed no group differences in how the three groups liked their postcards, F(2, 61)=0.32, p=.7. Self report ratings made immediately following discarding revealed significant group differences in all four emotions (Distress, Anxiety, Sadness, Guilt and Anger, all p's <.05). For Distress, Anxiety, Sadness and Guilt, Tukey's HSD post hoc testing revealed that both hoarding groups scored significantly higher than the control group (p's<.05) but did not differ from one another. Post hoc testing revealed that the hoarding with excessive acquisition group experienced more Anger than the Control group (p=.03), but the hoarding without excessive acquisition group did not differ from the control group (p=.19).

We next conducted a 2X3 repeated measures ANOVA in which the grouping variable was expanded to include the excessive acquisition specifier (hoarding with excessive acquisition, hoarding without, and control) to elucidate any differences across these groups from baseline to post-discarding. Means from this analysis are presented in *Figure 11*. In this analysis there was an effect of block, F(1, 57)=3.87, p=.05, but no significant block X group interaction, F(2, 57)=0.63, p=.54. There was a significant effect of group, F(2, 57)=6.31,

$p<.01$. Tukey's Honestly Significant Difference (HSD) post hoc testing revealed that the control group had smaller mean startle responses compared to both the hoarding with and without excessive acquisition groups (p's=.05), but no difference between the two hoarding groups (p=.93).

Discussion

In the present investigation, we used measures based on eyeblink startle responses to investigate information processing and emotional responses in association with hoarding symptoms. Our measure of information processing was PPI, which has primarily been used as a tool in the study of schizophrenia and linked to deficient gating of irrelevant thoughts and perceptions. Gating deficits appear relevant in OCD (Hoenig et al., 2005), and we postulated that they might also extend to hoarding. This hypothesis was not supported however. To summarize, our results indicated no association between low PPI and hoarding disorder. We also considered the possibility that PPI was related to psychiatric comorbidity. However, we found no significant differences in PPI scores when comparing hoarders with and without comorbid diagnoses to control participants. PPI scores were also unrelated to medication status, with hoarding patients using and not using current medications having equivalent PPI scores.

These null findings should be considered carefully, especially in light of the importance of information processing and neurocognitive deficits in theoretical accounts of hoarding disorder. One important possibility is that our measure of information processing, PPI, taps into domains of information processing that are different from those impaired in hoarding disorder. Previous research has investigated the way people who hoard process information in the domains of decision making and sustained attention and found deficits in

both categorizing information and sustaining attention. In the present study, we assessed attentional problems and difficulty making decisions by two self-report questionnaires and found that, congruent with previous research, the hoarding group did poorer on these measures. However, these measures were not at all correlated with PPI performance.

The present results suggest that hoarding disorder is not associated with PPI deficits, which are generally understood as failures in sensorimotor gating. Poor sensorimotor gating has primarily been interpreted as indicating difficulty suppressing irrelevant thoughts and inhibiting actions. Thus, the null finding in PPI scores suggests that hoarding problems may not involve inhibitory failure. This result is congruent with other findings utilizing paradigms that also relate to inhibitory processes. For example, Fillon and colleagues (1999) suggested that the Wisconsin Card Sorting Task assesses an inhibitory process (as the participant must inhibit a response that was previously correct) that may share an underlying neurophysiological basis with that assessed by PPI (Filion, Kimberle, & Hazlet, 1999). In support of this notion, Butler et al (1991) reported that a subgroup of schizophrenic patients with poor performance on the WCST had impaired PPI relative to those whose WCST performance was not impaired. Two studies have used the WCST in hoarding samples, with both finding no link between hoarding and poorer performance on the WCST (Lawrence et al., 2006; Grisham et al., 2007). In addition, a recent study found no differences between a sample of hoarding participants and a healthy control group on the affective Go/No-go task, another measure described in terms of response inhibition (Grisham et al, 2010). This converging evidence suggests that hoarding problems are not specifically related to underlying problems with suppressing thoughts or inhibiting actions. Although the dominant interpretation of PPI has characterized it as a measure of sensorimotor gating, this

interpretation is not without limitations. The sensorimotor gating model is based on the postulation that inhibiting the startle response to a loud tone in order to process a prepulse relates directly to the brain's ability to focus on certain information while filtering out and not responding to other cues. This explanation followed the frequently observed finding of reduced PPI in patients with schizophrenia with psychotic symptoms (Braff & Geyer, 1990). The sensorimotor gating interpretation suggests that the psychotic symptoms experienced by schizophrenics are the result of impaired internal gating mechanisms (i.e., hallucinations as a failure to inhibit irrelevant sensory and perceptual information; Braff & Geyer, 1990). Similarly, deficient sensorimotor gating has been invoked as an explanation for the relation between reduced PPI and other disorders, such as difficulty gating obsessions in OCD (Hoenig et al., 2005). A limitation of these explanations is that they link underlying neurobiological processes to psychological symptoms in an ad hoc fashion, based on intuition and the superficial similarity between inhibiting startle responses and failure to suppress problematic thoughts and behaviors. Other interpretations of PPI have been advanced. For example, as reviewed by Blumenthal (1999), Graham's protection theory suggests that reduced PPI is caused by a failure to process the initial prepulse, rather than a failure at inhibiting the response to the larger pulse. This interpretation would suggest that patient groups evidencing low PPI suffer from problems with the early detection and processing of weak stimuli, rather than difficulties with inhibiting responses.

Regardless of how PPI deficits are interpreted, our study suggests that hoarding is distinct from other disorders that are characterized by such deficits. Notably two studies found low PPI in OCD samples (Hoenig et al., 2005; Swerdlow et al., 1993). PPI may be another domain in which differences between hoarding and OCD are present, supporting the

separation of the two conditions (Mataix-Cols et al., 2010). However, this conclusion should be considered tentative given that a recent study also reported no PPI deficits in an OCD sample (de Leeuw et al., 2010). In addition, the present study did not include a separate group of OCD patients, limiting the comparisons that can be made.

In the second part of this work, we investigated emotional processing in relation to hoarding symptoms. We used AVSM in order to compare how the hoarding and control groups emotionally processed a standardized series of valenced images. We expected that the control group would show a linear pattern of increased startle magnitude in the presence of the pleasant, neutral and unpleasant images as is typically reported. We hypothesized that the hoarding group would not show this same linear pattern of increasing startle given that AVSM responses are different across a range of pathologies (Vaidyanathan, Patrick, & Cuthbert, 2009). This hypothesis was not supported, however, as both groups demonstrated the same linear pattern of increased startle magnitude across picture valence. There remained no effect of group when considering the effect of comorbid disorders in the hoarding group. These results suggest that the hoarding and control groups responded similarly to the emotion-evoking images. The hoarding group did not show potentiated startle in the presence of positive images as has been reported in depressed samples (Dichter et al., 2004) or especially exaggerated startle responses in the presence of negative scenes as would be expected in phobias (Vaidyanathan, Patrick, & Cuthbert, 2009).

Evaluation of the self-reported ratings of picture pleasantness resulted in no group differences, which is congruent with AVSM startle responses, which both suggest similar emotional processing of those images. However, there was a group difference in self reported ratings of arousal, with the hoarding group rating all picture categories as being more

arousing on average. This result is interesting, given findings that modulation of startle responses in the presence of affective images is especially pronounced for highly arousing images (Bernat, Patrick, Benning & Tellegen, 2006). This would suggest that the images in this study may have been more effective at modulating startle in the hoarding group. However, no significant interaction between group and image valence was observed, suggesting equivalent startle modulation. The finding of increased arousal ratings in the hoarding group is interesting in its own right and might relate to increased general arousal-reactivity in the hoarding group.

We also compared startle responses in the presence of images of clutter. Both the hoarding and control groups rated the clutter images as being similarly unpleasant (though again, the hoarding group rated the images as being more arousing). However, comparison of startle magnitudes failed to find differences between the clutter and neutral image categories for either the hoarding or control groups. Both groups demonstrated enhanced startle magnitudes for negative images compared to clutter images. These results suggest that the clutter images were more similar to the neutral images than the negative images in terms of affective modulation. However, this effect was the same for both groups, as there was no interaction between valence and group membership. Thus while we had expected that the clutter images to be experienced as more unpleasant in the control group compared to the hoarding group, this hypothesis was not supported, as both groups responded equivalently. An important limitation of this portion of the study is that the clutter images were standardized for both groups and did not reflect personal possessions, but instead general clutter. Therefore it remains unclear how hoarders respond to images of their own clutter.

Although no differences emerged in the AVSM portion of the study, the hoarding group did demonstrate enhanced general startle reactivity compared to the control group, which supported our hypothesis. We also devised a discarding task for the present study (discarding a postcard) in order to test the hypothesis that differences in startle reactivity would be exaggerated during symptom provocation. However, we found that startle reactivity actually decreased for both groups following the discarding. Self-report ratings revealed that discarding the postcard was successful at provoking more distress in the hoarding group than the control group. This result is discrepant from the finding of equivalent startle reduction across groups following the discarding. One potential explanation for this finding is that the induced emotion following the discarding task did not last long enough to be detected in post-discarding startle block (which was initiated after the self-report ratings were made and lasted for four minutes). An additional potential explanation for the decreased startle response from baseline to discarding blocks concerns the possibility that startle responses had rebounded after the AVSM block was administered (during which time the participants were allowed to rest) and habituated during the baseline block and reached an asymptote during the post-discarding block. In support of this possibility, a series of supplementary analyses[2], revealed that when we re-ran those analyses excluding the first three trials during the baseline block (the trials that would have been most influence by habituation) there was no significant reduction in startle magnitude from baseline to post-discarding. There remained a significant effect of group for startle responses collected during the post-discarding block, with the hoarding group again showing enhanced startle reactivity.

These results support our hypothesis of increased general startle reactivity in association with hoarding, and this group difference remained significant even after

accounting group differences in levels of depression, anxiety and stress. In addition, these results were not attributable to the presence of comorbid disorders in the hoarding group, as both hoarders with and without other current pathology had enhanced startle relative to the control group. Thus, the finding of elevated startle in the hoarding group appears to be robust. Neurobiologically, this finding suggests that hoarding is associated with increased activity in the extended amygdale, particularly the bed nucleus of the stria terminalis (BNST), which mediates persistent increases in startle reactivity (Vaidyanathan, Patrick, & Cuthbert, 2009). Enhanced general startle has been reported in several anxiety disorders, including PTSD, OCD, and GAD (see Lang & McTeague, 2009 for review). Our study suggests a psychophysiologic commonality between hoarding and these conditions. Although they require confirmation in other samples, these results are in concert with the suggestion that hoarding disorder should be categorized as a primarily anxiety-related problem, to be included in the anxiety disorders module of the upcoming revised DSM (Mataix-Cols et al., 2010).

Limitations and Future Directions

Several limitations of the present study should be noted. As mentioned previously, our finding that hoarding is not associated with impaired sensorimotor gating was indexed by a single measure of this construct (PPI of the acoustic startle). To achieve greater confidence in the conclusion that hoarding does not involve difficulties related to inhibitory failure, it would be beneficial to employ additional measures. One such measure is the P50 suppression paradigm, a measure of sensory gating that involves measuring evoked response potentials (ERP) to two closely presented auditory stimuli (Adler et al., 1982). Performance based measures of deficient inhibition have also been used in studies on hoarding (Grisham et al.,

2010; Lawrence et al. 2006) but were not included in the present study. Future research should combine multiple inhibition paradigms in concert in order replicate our findings.

Another limitation of the present study concerns the sample. We compared only two groups (hoarding and healthy control), so the conclusions we can draw are limited, as we are not able to compare the results from our sample to other clinical samples. For example, whereas two studies found that OCD is associated with low PPI (Hoenig et al., 2005; Swerdlow et al., 1993), we did not include an OCD patient group and therefore cannot use the present study to directly compare hoarding to OCD. In addition, we found elevated general startle reactivity in hoarding, as has been reported for several anxiety disorders, including GAD (Ray et al., 2009), PTSD (Morgan et al., 1995), and OCD (Buhlmann et al., 2007). Without another anxiety disorder group, we cannot directly compare the magnitude of this difference. Therefore, future study is warranted in order to directly compare startle responses between individuals with hoarding and other anxiety disorders, as well as other non-anxiety related conditions. Finally, our study employed a single time point, cross-sectional design. Therefore, although we found increased startle in our hoarding group, we cannot determine if this enhanced reactivity is a cause or consequence of hoarding symptoms, or if it relates to an unmeasured third variable. Future study could use longitudinal designs to determine if elevated startle precedes the onset of hoarding problems or develops later.

Conclusion

Pathological hoarding is a disabling condition that is receiving increased empirical attention and is likely to be included as a new diagnostic entity. The results of the present study suggest that this condition does not involve deficient sensorimotor gating, a measure of

processing often found to be impaired in schizophrenia. Rather, hoarding may be related to other domains of information processing, including impaired decision making and difficulty sustaining attention. In the present study, the hoarding group did not differ from the control group in how their startle responses were modulated by affective imagery. However, the hoarding group demonstrated elevated general startle reactivity. Elevated startle has been noted in several anxiety disorders, suggesting a psychophysiologic commonality between hoarding and these conditions. More research is needed to confirm these results in an independent sample, and with more extensive comparison groups.

Endnotes

[1] As these study measures were added after the study had already begun, they were only available for 17 of the 33 participants in the hoarding group.

[2] To test the possibility that habituation might explain the decrease in startle magnitude from the baseline to post-discarding blocks we recomputed the magnitude for the baseline block excluding the first three startle trials, which would have been most influence by habituation. We then re-ran the Block (baseline, post-discarding) by Group (hoarding, control) 2X2 repeated measures ANOVA. In this analysis, there remained a significant effect of Group, $F(1, 58)=12.32$, $p=.001$, with the hoarding group having larger startle responses on average. However, there was no effect of Block, $F(1, 58)=0.26$, $p=.61$ and no significant Block X Group interaction, $F(1, 58)=0.02$, $p=.89$. We also re-ran the 2X3 repeated measures ANOVA in which the grouping variable was expanded to examine the effect of comorbidity in the hoarding group. Using the revised calculation of the baseline block, there was no longer a main effect of Block, $F(1, 57)=0.23$, $p=.64$, and also no significant Block X Group interaction, $F(2, 57)=0.16$, $p=.85$. The effect of group remained significant, $F(2, 57)=6.09$, $p<.01$, with post hoc testing indicating that both the pure hoarding and comorbid hoarding groups scoring higher than the control group (p's$<.01$). The two hoarding groups did not differ from each other ($p=.83$).

Table 1

Demographic and Clinical Characteristics for the Hoarding (n = 33) and Control (n = 30) Groups

Variable	Hoarding	Control	Test of the difference
Demographic characteristics			
Mean age (SD)	48.15 (15.96)	42.2 (14.0)	$t = 1.56$, $p > .12$
No. Female (%)	23 (69.7)	19 (63.3)	$\chi^2 = 0.29$, $p > .39$
Racial/ethnic background			$\chi^2 = 4.87$, $p > .30$
No. White (%)	24 (72.7)	24 (80.0)	
No. African Amer. (%)	8 (24.2)	5 (16.7)	
No. Asian (%)	1 (3.0)	1 (3.3)	
Clinical characteristics			
HRS-I	23.76 (3.66)	0.5 (0.82)	$t = 35.56$, $p < .001$
SI-R	58.67 (11.08)	7.57 (5.75)	$t = 23.27$, $p < .001$
SCI	105.18 (23.85)	38.0 (12.67)	$t = 14.34$, $p < .001$
CIR	10.44 (2.91)	3.2 (0.55)	$t = 13.82$, $p < .001$
DOCS	15.24 (12.35)	3.03 (5.68)	$t = 5.12$, $p < .001$
IS	47.89 (10.91)	30.38 (10.16)	$t = 5.58$, $p < .001$
ADHDSS-Attention	18.11 (5.77)	11.69 (4.22)	$t = 4.41$, $p < .001$
ADHDSS-Hyperactivity	15.67 (5.6)	12.0 (3.86)	$t = 2.44$, $p = .03$
DASS-Depression	11.58 (10.79)	2.13 (3.16)	$t = 4.78$, $p < .001$
DASS-Anxiety	6.0 (5.81)	1.87 (4.2)	$t = 3.21$, $p < .01$
DASS-Stress	13.7 (9.11)	7.33 (8.34)	$t = 2.88$, $p < .01$

Note. HRS-I=Hoarding Rating Scale-Interview; SI-R = Saving Inventory-Revised; SCI = Saving Cognitions Inventory; CIR = Clutter Image Rating; DOCS = Dimensional Obsessive Compulsive Scale; DASS = Depression Anxiety and Stress Scale-21; ADHDSS=Attention Deficit Hyperactivity Disorder Symptom Scale; IS=Indecisiveness Scale.

Table 2

Mean (SD) Valence and Arousal Ratings for IAPS Images by Group

	Valence			
	Pleasant	Neutral	Unpleasant	Clutter
Hoarding	1.80 (.8)	-0.42 (.98)	-3.28 (.92)	-2.44 (.94)
Control	1.98 (1.0)	-.37 (1.07)	-3.15 (.83)	-2.21 (.9)
	Arousal			
	Pleasant	Neutral	Unpleasant	Clutter
Hoarding	4.59 (1.61)	2.42 (1.34)	4.99 (2.82)	4.39 (2.37)
Control	3.69 (2.02)	1.11 (1.06)	4.49 (2.46)	3.04 (2.42)

Figure 1. Percent PPI by Group

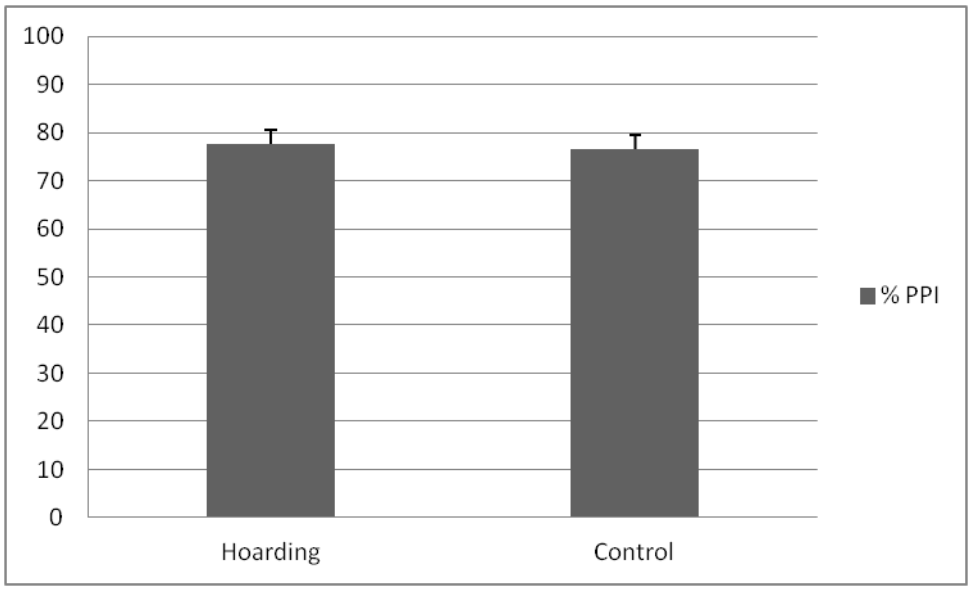


Figure 2. Percent PPI by Group

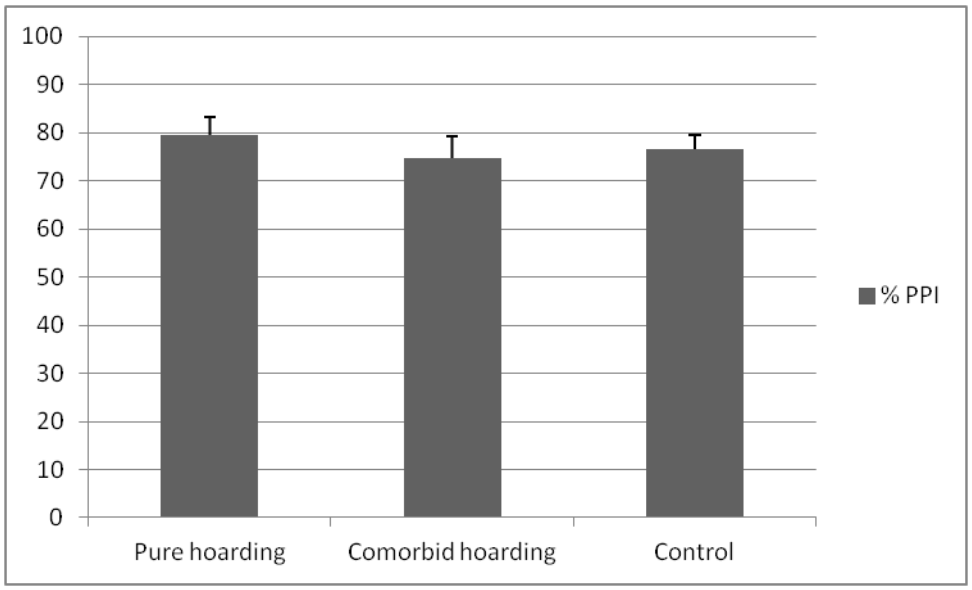


Figure 3. Valence Ratings of IAPS Images by Group.

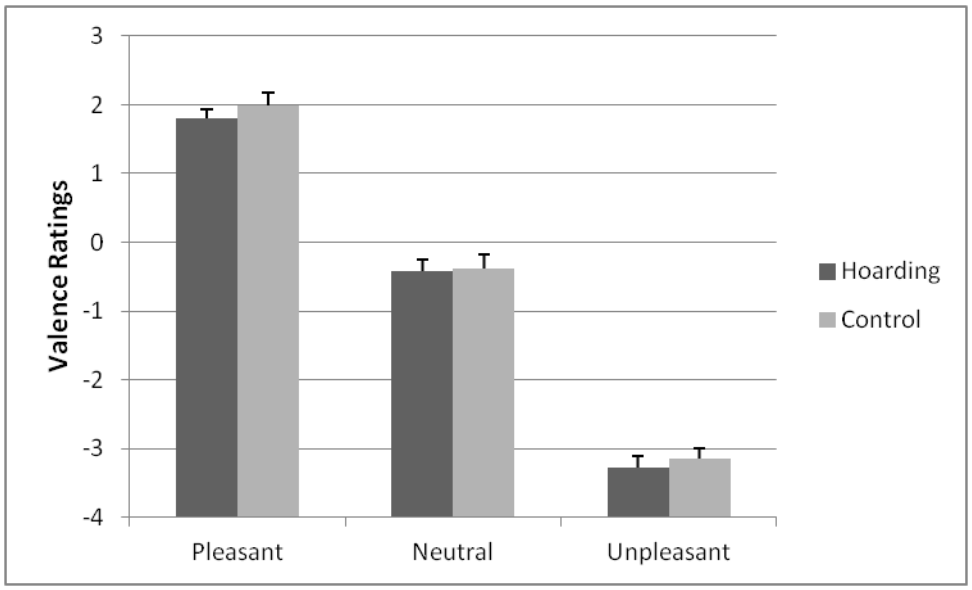


Figure 4. Arousal Ratings of IAPS Images by Group.

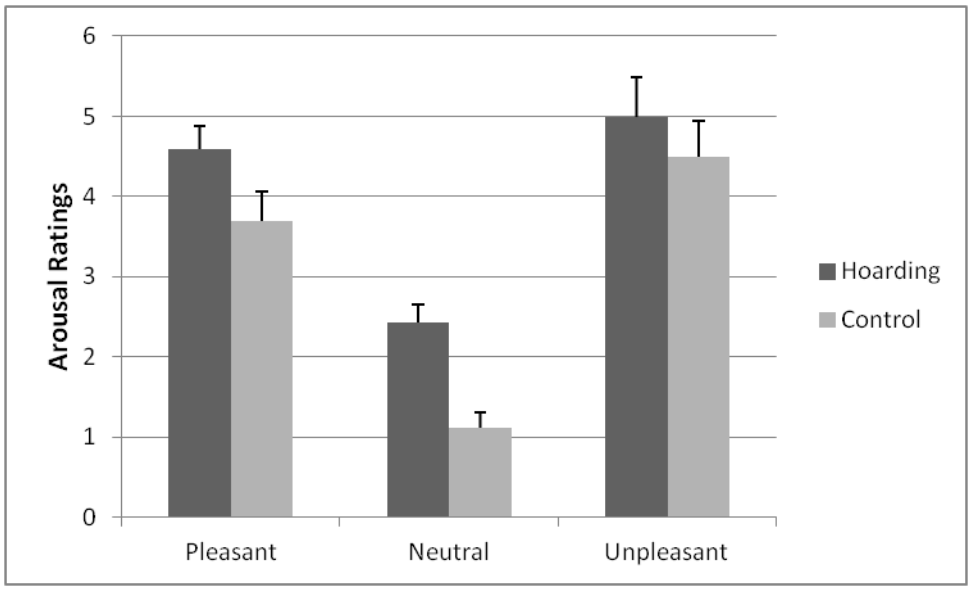


Figure 5. AVSM Startle Magnitude by Group.

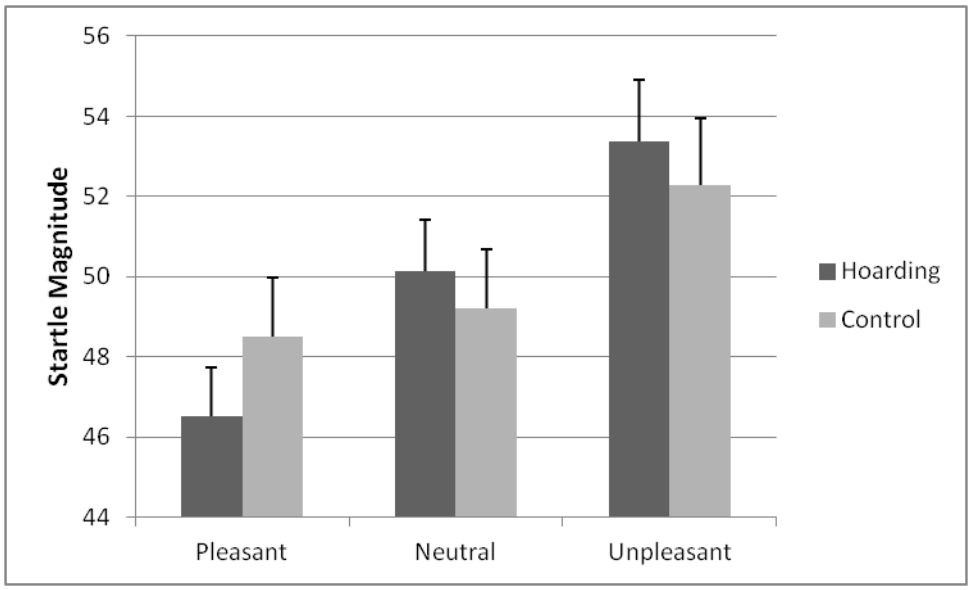


Figure 6. AVSM Startle Magnitude by Group.

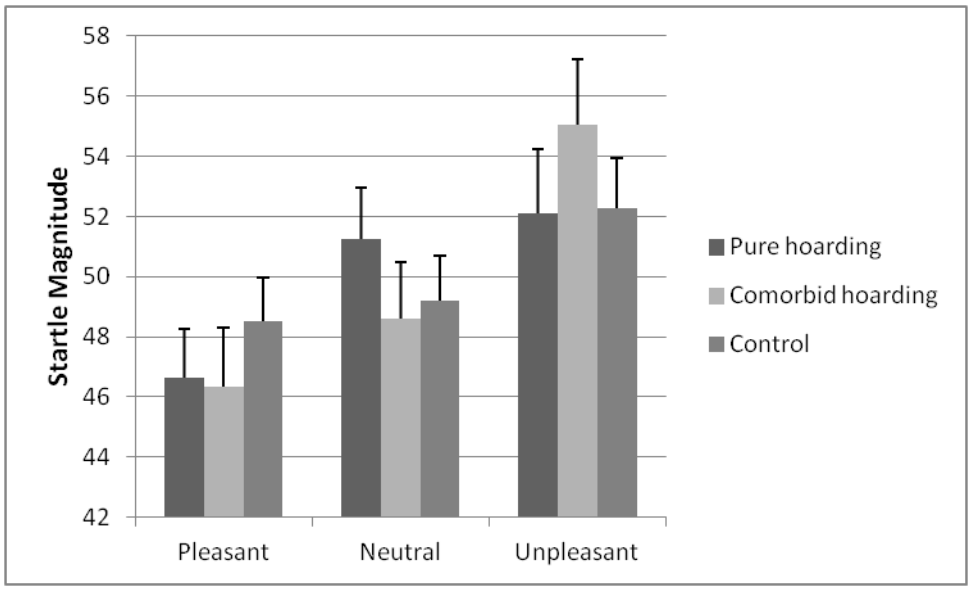


Figure 7. Startle Responses to Clutter and Neutral Images by Group.

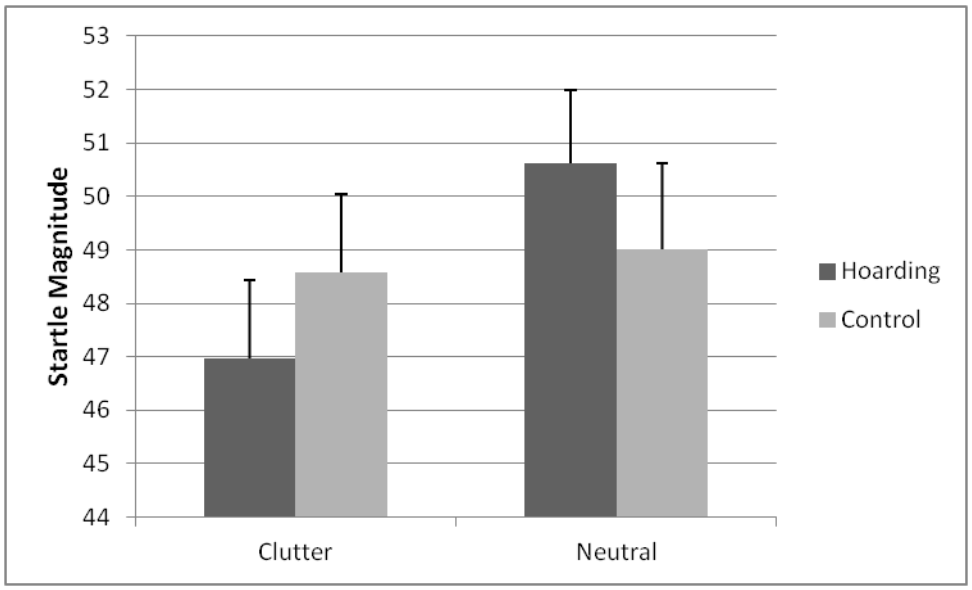


Figure 8. Startle Responses to Clutter and Neutral Images by Group.

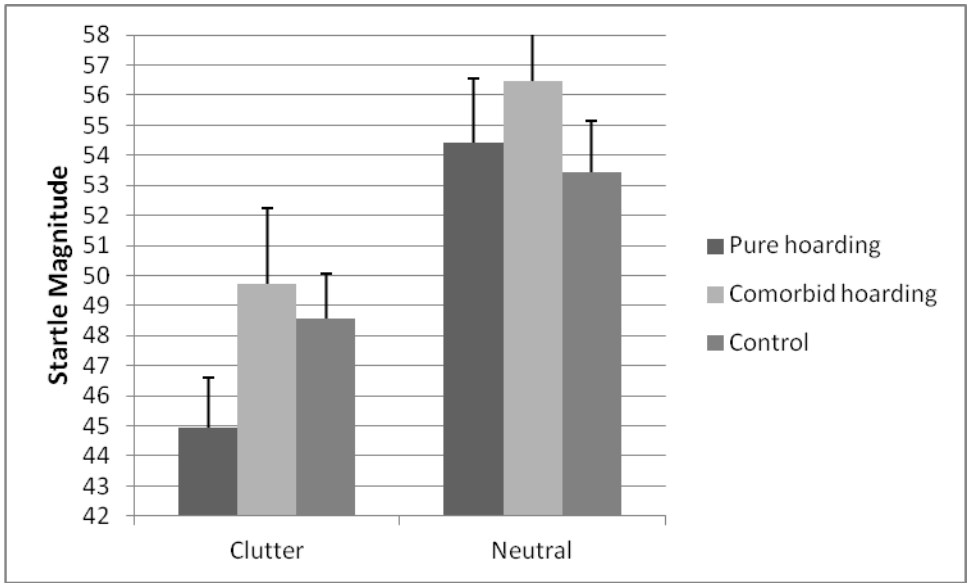


Figure 9. Startle Responses at Baseline and Post Discarding by Group.

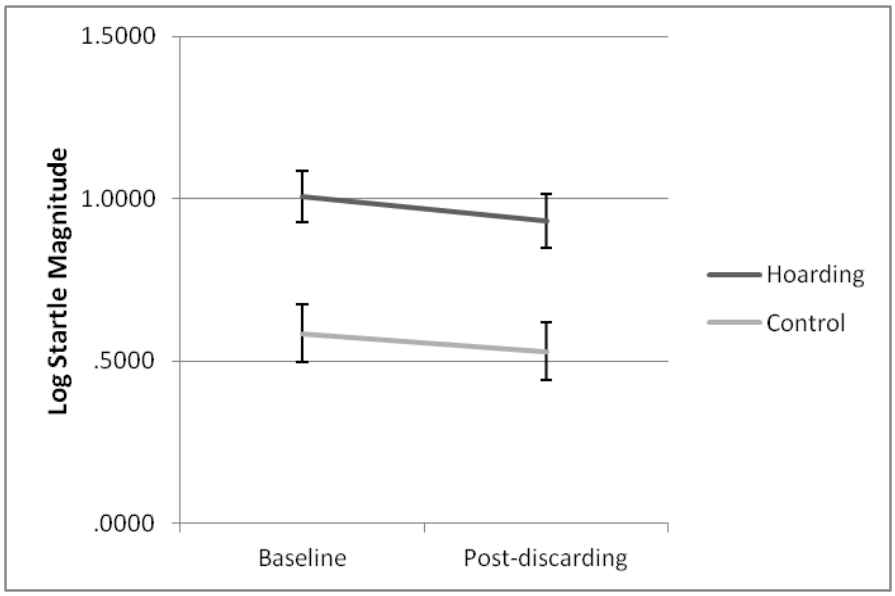


Figure 10. Startle Responses at Baseline and Post Discarding by Group.

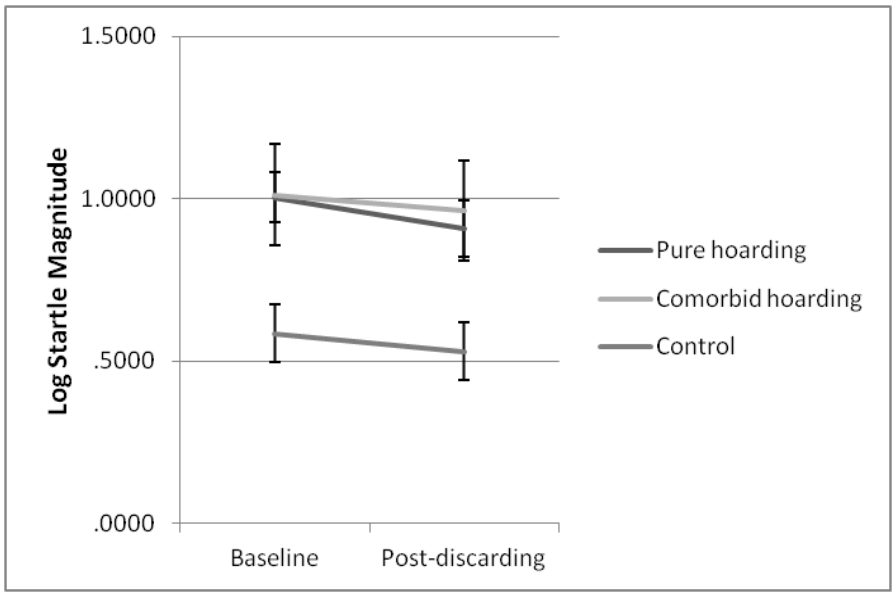
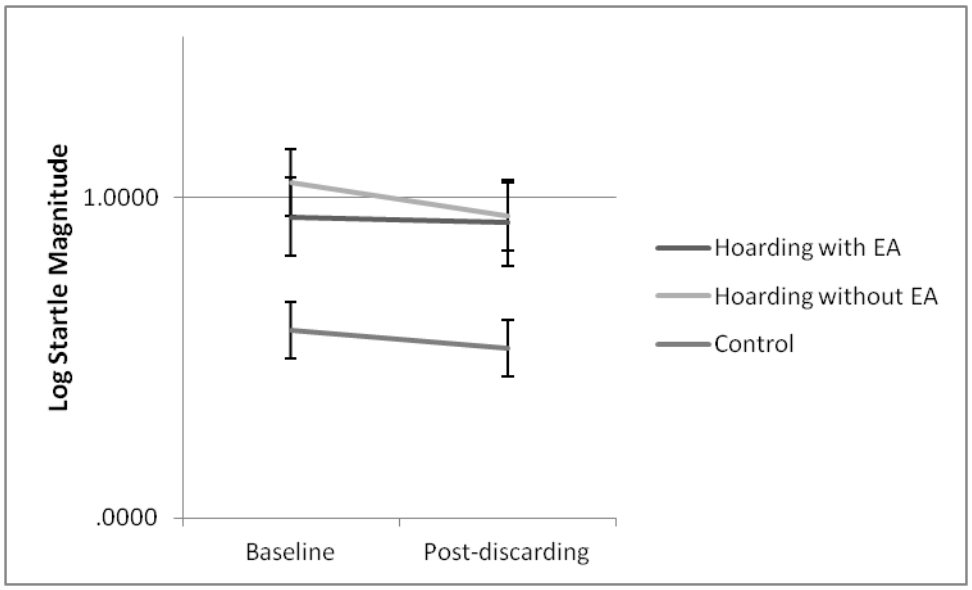


Figure 11. Startle Responses at Baseline and Post Discarding by Group.



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