From Freud to Android: Constructing a scale of uncanny feelings

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Abstract

The uncanny valley is a topic for engineers, animators, and psychologists, yet uncanny emotions are without a clear definition. Across three studies, we developed an 8-item measure of unnerved feelings, finding that it was discriminable from other affective experiences. In Study 1, we conducted an exploratory factor analysis that yielded two factors; an unnerved factor, which connects to emotional reactions to the uncanny, and a disoriented factor, which connects to mental state changes more distally following uncanny experiences. Focusing on the unnerved measure, Study 2 tests the convergent and discriminant validity, concluding that participants who watched an uncanny video were more unnerved than those who watched a disgusting, fearful, or a neutral video. In Study 3, we determined that our scale detects unnerved feelings created during early 2020 by the coronavirus pandemic; a distinct source of uncanniness. These studies contribute to the psychological and interdisciplinary understanding of this strange, eerie phenomenon of being confronted with what looms just beyond our understanding.

Introduction

Why were we equipped with this eerie sensation? Is it essential for human beings? (Mori, 1970, p. 33).

Indeed, we get an impression that many languages are without a word for this particular shade of what is frightening (Freud, 1919/2003, p. 220).

It is strange to think that a Japanese roboticist and Sigmund Freud were puzzled by the same phenomenon—yet uncanniness concerned them both. As engineers develop increasingly human-like robots, they risk creating ghoulish monsters instead of helpful companions (MacDorman & Ishiguro, 2006; Hanson, 2005). And our Freudian nightmares do not end there; animators are becoming more skilled at mimicking life, but their designs risk being plunged into the uncanny valley (Mori, 1970; Tinwell et al., 2011). What emotions characterize these kinds of surreal and eerie experiences? Thus far, no one can precisely define uncanniness (Diel, Weigelt, & Macdorman, 2022; Wang, Lilienfeld, & Rochat, 2015). In this paper, we explore the concept of uncanniness, regarding what people experience when things are not quite as they expected. We developed a scale measuring uncanny emotions that draws on an array of theoretical perspectives.

The Uncanny Valley

Masahiro Mori (1970) introduced the world to the uncanny valley hypothesis. In an article published in the Japanese robotics journal, *Energy*, he proposed that people dislike objects that are almost, but not quite, human. According to the hypothesis, adding a touch of humanity can be a good aesthetic decision; stuffed animals, for example, are more likable than pet rocks. Adding too much, though, is a bad decision: Wax figures, humanoid robots, rubber hands, and corpses, feel eerie because they appear almost human (Mori, 1970). Mori predicted that people's

attraction to objects was distributed as a valley, increasing as objects appeared more human, but plummeting when they fell on the boundary between human and object. Despite mixed empirical support for the valley shape (e.g., Seyama & Nagayama, 2007; Mathur & Reichling, 2016; Burleigh, Schoenherr, & Lacroix, 2013; MacDorman et al., 2009) there is agreement on the core principle: objects with near-human qualities make people's skin crawl (Diel et al., 2022; Wang et al., 2015).

Measuring the uncanny

Mori (1970) described people's reactions to the uncanny valley as negative 'shinwakan', translated as negative affinity, which has been understood to mean lacking familiarity, warmth (Bartneck et al., 2009; Reichardt 1978), or alternately, having feelings of eeriness and creepiness (Gray & Wegener, 2012; Diel et al., 2022; Ho & MacDorman, 2010; Langer & Konig, 2018; MacDorman et al., 2009). The latter interpretation aligns with psychoanalytic descriptions of the uncanny (Wang et al., 2015; see also Freud, 1919; Jentsch, 1906) and more narrowly describes the phenomenological experience of encountering uncanniness (Diel et al., 2022; Ho & MacDorman, 2010). Most measurement strategies focus on eeriness (see Diel et al., 2022).

These strategies have fallen into two broad categories; the first is to measure participants' evaluations of a target, enabling researchers to pinpoint aesthetic features that contribute to eeriness. Ho and MacDorman (2010/2017) developed an eeriness measure, compatible with the Godspeed questionnaires (see Bartneck et al., 2008), which consists of semantic differential scales like Dull-Freaky, Bland-Uncanny, Plain-Weird, and Predictable-Eerie. Many investigations of the uncanny have used or adapted this measure (see Lischetzke et al., 2017; MacDorman & Chattopadhyay, 2016; Stein & Ohler, 2018; Tinwell et al., 2013; Złotowski et al., 2015). However, it is less useful as an indicator of emotions: the measure captures participants'

judgments, but not their own affective experiences. In other words, it is unclear whether participants feel eerie themselves, or simply associate the target object with eeriness.

The second, less common approach has been to measure emotions directly. In the past, researchers focusing on emotion have asked participants whether they feel ‘uneasy,’ ‘unnerved,’ and ‘creeped out’ (Appel, Izydorczyk, Weber, Mara, & Lischetzke, 2020; Gray & Wegner, 2012; Yam et al., 2021). These three items are brief, and not designed to be precise; instead, they have the advantage of being words that are “more frequently used and less ambiguous” than uncanny (Gray &Wegner, 2012, p. 126). Studies with children use a briefer measure, ‘How weird does it make you feel?’ (Brink, Gray, & Wellman, 2019). As far as we know, there have been no attempts to construct a comprehensive, validated scale measuring uncanny feelings.

The present scale construction strategy has three advantages: first, we measure feelings directly, which enables us to study experiences that are unfiltered by judgments of a target object. Second, we borrow from traditions and theoretical perspectives outside of human-robot interactions, developing a measure that is consistent with a psychoanalytic, surrealist, and existential perspective on uncanniness (see Breton, 1924; Becker, 1973; Freud, 1919/2003; Jentsch, 1906). Third, our systematic approach to measurement enables us to compare the construct with other related affective states (fear, disgust, anxiety) to find their similarities and their differences.

Theoretical Explanations for Uncanny Feelings

Before we launch into our investigation of uncanny emotions, we first consider some past evidence for the origins of the uncanny. We forward that uncanniness is a phenomenon that extends beyond encounters with life-like robots, more broadly describing encounters with events that violate expectations.

Perceptual and cognitive

Several explanations for the uncanny valley have focused on perceptual and cognitive mechanisms causing humans to react negatively to human-like objects (see Kätsyri et al., 2015; Wang & Lilienfeld, 2015). A prominent explanation emphasizes category uncertainty: objects that seem to fall upon the boundary between human and non-human resist categorization (Cheetham, Suter, & Jäncke, 2011; Ramey, 2006), and consequently elicit negative affect (Burleigh & Schoenherr, 2015). Uncanniness may therefore be a product of cognitive conflict that occurs when two different categories are simultaneously activated (Weis & Wiese, 2017).

This explanation draws upon contemporary theories of perception and cognition, but also builds on an early theoretical perspective: Ernst Jentsch (1906) framed uncanniness it as a general sense of uncertainty, and a lack of orientation. By his account, uncanny feelings arise from "the human desire for the intellectual mastery of one's environment" (p. 16). Studies forwarding a category uncertainty explanation use morphed human-nonhuman images to demonstrate that participants attribute the least certainty, and least positive evaluations, to objects on the category boundary (e.g., Cheetham et al., 2015; Yamada, Kawabe, & Ihaya, 2013). Lischetzke and colleagues (2017) found that participants presented with a continuum of morphed human and robot images ascribed eeriness to those that fell on the category boundary.

A distinct, but related explanation concerns perceptual cues; objects elicit eeriness when they possess mismatched features, regardless of whether they occupy a category boundary (Kätsyri et al., 2015; MacDorman & Chattopadhyay, 2016). Studies supporting this explanation have found that altering the size, shape, or realism of specific features on human subjects elicits eeriness (MacDorman, Green, Ho, & Koch, 2009; Seyama & Nagayama, 2007). In theory, these

alterations cause perceptual tension, which in turn drives the negative emotions associated with uncanniness (MacDorman & Chattopadhyay, 2016; Moore, 2012).

Mind perception

Another explanation is that the concept of robot minds creates discomfort (Crowell, Deska, Villano, Zenk, & Roddy Jr, 2019; Gray & Wegner, 2012; Schein & Gray, 2015). A capacity for experience is typically reserved for humans (Gray, Gray, & Wegner, 2007), though objects that fall into the uncanny valley may be perceived as having an internal life. Gray and Wegner (2012) found that machines described as experiencing hunger, fear, and other emotions, elicited the most eeriness.

The mind hypothesis shifts focus from aesthetics to uncanny *scenarios* and uncanny *concepts*—robots possessing minds, and humans lacking minds, create uncanniness regardless of the physical appearance of those robots and humans. Though perceiving minds cannot account for every instance of eeriness (Gray & Wegner, 2012), the insight that it accounts for some has paved the way for studies that ascribe the uncanniness label to *concepts*, such as chatbots that possess artificial intelligence (see Stein & Ohler, 2017).

Existential motivations

According to the existential account, uncanny objects make people think of death, both on an aesthetic level (appearance corpse-like), and on a conceptual level— people are reminded of fearful notions that humans are no more than machines (MacDorman & Ishiguro, 2006; see also Ramey, 2005). This account derives from Terror Management Theory, which states that reminders of death create existential anxieties which enhance people's motivations to defend their worldview (Goldenberg et al., 2001). Supporting this explanation, MacDorman and Ishiguro (2006) found that people who saw an uncanny image engaged in behaviours that are

typical of being reminded of death, preferring a worldview-affirming target over a worldview-threatening one. The existential account is theoretically linked to mind perception: the belief that humans are not special or unique elicits anxieties (Greenberg, Pyszczynski, & Solomon, 1986); thus, robot minds may constitute an existential threat (MacDorman & Entezari, 2015).

Violated expectations

The perceptual, cognitive, conceptual, and existential explanations all converge under the perspective of violating expectations—objects create a sense of unease by appearing simultaneously familiar and unfamiliar (MacDorman et al., 2009; see also Wang et al., 2015; see also Freud, 1919/2003; Heidegger, 1927/1962). The woman whose glazed eyes and rigid movements reveal her to be an android; the wax figurine that resembles a celebrity, but upon closer inspection, is disturbingly lifeless; a painting of a familiar landscape, but that is littered with melting clocks; these are examples of familiar objects violating people's expectations, and therefore candidates for uncanniness (Mitchell et al., 2011; Saygin et al., 2012).

Violated expectations depart from Jentsch's psychoanalytic account, instead echoing Freud (1919/2003) who described the uncanny as something that was once familiar, now made unfamiliar. A dark thought that has been hidden from consciousness, or a sense of supernatural coincidence, are events that make one feel a lack of control or free will, like questioning whether one possesses a soul, acting instead on 'compulsion' or in 'repetition' (p. 12). According to Freud, one anticipates a tolerable level of uncertainty in their lives; unfamiliarity is disturbing precisely when one is prepared for familiarity. Having one's expectations undermined is alienating. This description influenced the surrealist movement, which Andre Breton (1924/1969) described as the uncomfortable juxtaposition of the familiar and the unfamiliar.

Corroborating these theoretical claims, research finds that surrealism can be unnerving; an absurd Kafka story causes people to experience meaningless, whereas viewing Magritte's "The Son of Man" makes them more likely to express a need for structure (Proulx, Heine, & Vohs, 2010). Expectations are violated by exposure to surreal art and film (Proulx et al., 2010; Randles, Heine, & Santos, 2013), by surprising occurrences, like finding oneself arguing for a position that one doesn't endorse (e.g., Randles, Inzlicht, Proulx, Tullett, & Heine, 2015) or even by low-level conflicts, like mismatched word pairs (Randles, Proulx, & Heine, 2011) or seeing a red king of spades (e.g., Randles, Benjamin, Martens, & Heine, 2018).

Expectancy violations appear to activate neural regions associated with anxious arousal (Gray and McNaughton, 2000; McNaughton & Corr, 2004; see also Jonas et al., 2014). People experience this arousal when worldviews are threatened, or sense-making goals are frustrated (Heine, Proulx, & Vohs, 2006; Holbrook & Sousa, 2013; McGregor et al., 2010). Therefore, the uncanny may characterize the arousal associated with encountering expectancy violations.

Distinguishing uncanniness from other emotions

As reviewed above, there have been many different perspectives on what causes the uncanny, accompanied by compelling empirical evidence; objects and events that defy categorization, strain perceptual processes, threaten human uniqueness, or violate expectations, may all cause uncanniness. But what has largely been left out of these competing accounts is how it *feels* to experience the uncanny. While the above theories offer explanations for why uncanny objects are so bothersome, none have described the affective experience.

It is possible that uncanniness may be an entirely distinct category of emotion, or it may instead be derivative of other emotions. Ho and colleagues (2008) determined that eeriness was strongly positively correlated with other more familiar sensations, like disgust, and fear.

Why might disgust be related to uncanniness? A theoretical perspective is that if an android moves rigidly or has subtle morphological differences from healthy people, it could look diseased (MacDorman et al., 2009). In theory, disgust helps humans to avoid contamination (Rozin, 1987) thus thoughts of contamination could explain why people are motivated to avoid uncanny objects. Supporting this idea, MacDorman and Entezari (2015) found that people who were disturbed by reminders of humans' creaturely nature perceived more eeriness in androids.

In addition, fear has been explicitly linked to uncanniness. Freud (1919/2003) characterized uncanny objects as subsets of fearful objects, and existential explanations for the uncanny support existential terror as a potential mechanism (MacDorman & Ishiguro, 2006). Mori (1970) also suggested uncanny objects can appear sinister and may signal threat, and more recent research has shown that people do explicitly connect uncanny faces with perceptions of threat (Wang & Rochat, 2017).

Uncanny feelings may share qualities with disgust and fear. Yet there are many uncanny objects that would seem to be neither disgusting nor scary; for example, Disney's computer-generated imagery version of the Lion King (2019) and the Polar Express (2004) are frequently described as uncanny (Rivera, 2019; Geller, 2008) but it is hard to identify anything disgusting or frightening about them. Moreover, uncanniness goes beyond just disgust and fear to include broader concepts, like the surreal and unfamiliar. In describing surreal situations—a ghost town or an abandoned city square—neither fear nor disgust seem appropriate.

Overview of studies

Across three studies, we developed and validated a scale measuring uncanny feelings. In Study 1, we generated and refined a set of uncanny items. In Study 2, we examined the factor structure using confirmatory factor analysis, and tested the validity of the scale by examining its

relationship with related constructs. In Study 3, we investigated how people thought about and responded to the 2020 coronavirus pandemic and evaluated their responses to our novel uncanniness scale. These studies contribute to the psychological and interdisciplinary understanding of this phenomenon of being confronted with what looms just beyond our understanding. In all studies, participants provided informed consent and the studies received ethics approval from the institutional review board from our university: H17-02918.

Study 1

Participants watched one of three videos; two were expected to elicit uncanny feelings, and one was a control. We created a list of items to assess uncanny feelings and conducted an exploratory factor analysis.

Methods

Participants

We aimed for an item-subject ratio of 1:10 within the experimental conditions. On this basis, we recruited 1512 Americans from Amazon's Mechanical Turk (Mturk). We excluded 119 participants for failing one of two attention check questions, or for reporting (1) they only watched part of the clip or (2) watched a clip that includes important audio with the sound turned off. We were left with a sample of 1393 (see Table 1 for demographic data from Studies 1-3).

Table 1. Demographics for Studies 1-3.

			% Ethnicity or Race						
Study	Age *M* (SD)	Female %	White or European	Black or African	Latinx	East Asian	South Asian, Southeast Asian, Arab	Pacific Islander, Native American/Alaskan Native, Native Hawaiian	More than one Ethnicity or Race
1	34.48 (11.22)	59	61	10	6	5	1	1	3
2	37.27 (11.88)	63	70	9	6	7	1	1	4
3	39.27 (13.59)	50	62	14	6	4	1	1	3

Note. Participants entered their own gender and ethnicity in a free-response textbox. From each study, there were participants who did not enter their gender (Study 1 n=183, Study 2 n = 2, Study 3 n = 3) participants who identified as

nonbinary (Study 1 n = 7, Study 2 n = 7, Study 3, n = 3) and participants who did not enter a codable ethnicity or race (Study 1 n = 147, Study 2 n =27, Study 3 n =40),

Item generation

We generated items based on how the concept of uncanniness has been discussed in Freud's "The Uncanny", Mori's (1970) article introducing the uncanny valley, and other scales measuring people's judgments about affective qualities of uncanny objects (see MacDorman & Chattopadhyay, 2016; Ho & MacDorman, 2010, 2017). We also generated items using translations of the German term for uncanny (*unheimlich)* to other languages (French, Spanish, Hebrew, English). We created 44 items that tapped into this construct in various ways (see the SOM Section 1). We asked participants to indicate on a 7-point scale how much each item characterized their current experience.

Procedure

Participants watched one of three videos; the first video showed a series of highly realistic animations and humanoid robots (Robots condition); the second video was a clip from a short surreal David Lynch (2002) film called "Rabbits" (Rabbits condition; previous studies have used this clip to elicit a sense of surrealness; e.g., Randles et al., 2013); the third control clip was a scene from the Peanuts TV series (all clips available on the OSF: https://osf.io/b4v9y/?view_only=83e0202e9de446cbaac17252cd2f3734). We expected that participants who viewed one of the first two clips would report experiencing more uncanny feelings than those in the control condition.

Results and Discussion

Exploratory Factor Analysis

We conducted a maximum likelihood factor analysis with direct oblimin rotation, allowing factors to correlate. The factor analysis was only conducted amongst participants

assigned to one of the two uncanny conditions (as we expected that only these participants would be experiencing uncanny feelings). The sample size of those who viewed either of the uncanny videos was $N = 967$. We had no a priori expectations of the factor structure.

We used an iterative strategy to determine the most effective measure of uncanniness, evaluating the initial factor structure, eliminating items with low loadings or high cross-loadings, and conducting a follow-up factor analysis. First, we investigated the number of factors to retain using the procedure of parallel analysis (Horn, 1965; Dinno, 2009). Parallel analysis compares the eigenvalues with those generated by simulated data to determine if they are capturing more than random noise (Horn, 1965). This procedure revealed a five-factor solution would fit the data; the first five eigenvalues were 22.62, 2.81, 1.39, and 0.98, and 0.93.

We investigated the loadings to determine if the factors represented meaningful semantic categories. The first three factors accounted for 48% of the variance, but factor 3 had few items loading more than .450 and accounted for only 12% of the variance (vs. 18% and 17%). We therefore removed items whose loadings were high on factors 3-5 but low on factors 1 and 2 (totalling six items; we include a detailed discussion of these eliminated items in SOM Section 1). Then, we re-analyzed the remaining items, which yielded a three-factor solution. We present loadings for the three-factor solution in the SOM (Section 1) so researchers interested in this alternate scale construction can investigate it.

Two-factor solution. Eliminating items with high cross-loadings yielded a 21-item scale with two factors. Among the remaining 21 items, eigenvalues for the two factors were 11.27 and 2.38. In our next step, we again eliminated three items with high cross-loadings, and two items that likely correlated because of some semantic quality unrelated to the construct (“Right now, I

lack control over my body" and "Right now, I lack control over my body", but we retained "Right now, I lack control over my thoughts").

We discovered two distinct factors, one we labelled unnerved and another we labelled disoriented feelings, that explained 34.5% and 27.5% of the variance respectively. The two factors correlated at r = .631, suggesting they were sensitive to different but related constructs. The model had good fit (RMSEA = .043, .90 CI [.037, .049], $\chi^2(89, N=965) = 248.72$, $p < .001$, $\chi^2/df = 2.79$, CFI = .985) and Cronbach's alpha was high for both scales (unnerved α=0.94, disoriented α=0.91). We present the item loadings in Table 2.

Table 2. Item loadings for the two-factor structure.

	Factor Loadings	
Item	Unnerved	Disoriented
I feel creeped out	**.891**	-.131
I am uncomfortable	**.871**	-.039
I am unsettled	**.861**	-.019
I have an eerie sensation	**.818**	. 022
I feel freaked out	**.781**	. 063
I am uneasy	**.781**	. 087
I feel very disturbed	**.772**	.090
I feel weird	**.720**	.108
I have a feeling that I'm not in charge of my actions	-.073	**.807**
Right now, I lack control over my thoughts	-.017	**.804**
Right now, many of my thoughts are about death	-.047	**.772**
I feel like I don't know anything anymore	.059	**.728**
I feel like I'm stuck in a pattern I can't get out of	-.042	**.693**
I feel like I'm being followed	.065	**.689**
I'm having dark thoughts right now	.147	**.659**
I'm feeling alienated	.143	**.628**

We observed that the unnerved factor was a face valid measure of eeriness as it has been described in the uncanny valley literature (see Ho & MacDorman, 2010; Mori, 1970). In contrast, the disoriented factor seemed a less face valid affective scale because many items reflect high-level cognitive reactions to encounters with the uncanny (e.g., right now, many of my thoughts are about death). And yet, it is consistent with the psychoanalytic account of uncanniness (see Freud, 1919; Jentsch, 1908) and some more recent existential accounts (see

MacDorman, 2005). We retained both factors in our follow-up studies and report on the disoriented scale in the SOM, though we focus on how the unnerved scale performed as an indicator of uncanny emotion.

Test of condition

A goal of Study 1 was to evaluate if our measure can differentiate between an uncanny and a neutral experience. Thus, participants in the uncanny conditions should score higher on the unnerved and disoriented scales than those in the control condition. A secondary goal was to compare reactions to two distinct elicitors of uncanniness; a human-like robot and a surreal clip; therefore, we compared mean levels in the Rabbits and Robots conditions. We conducted one-way ANOVAs predicting the eight-item scales from the experimental condition (Table 3).

Table 3. Unnerved and disoriented feelings by condition

Source	df	Mean square	F	*p*	η_p^2
		Unnerved			
Condition	2	341.61	150.36	<.001	.19
Error	1247	2.27			
		Disoriented			
Condition	2	38.99	28.30	<.001	0.02
Error	1248	1.38			

Unnerved. There was a significant effect of condition. The mean for Rabbits was the highest (M = 3.95, SD = 1.56), followed by Robots (M = 3.15, SD = 1.61), and control (M = 2.02, SD = 1.20). Follow-up tests with Holm-Bonferroni adjustments revealed that both experimental conditions produced significantly higher scores than control; Rabbits: $t(731.45) = 19.33$, $p < .001$, .95 CI [1.74, 2.13], $d = 1.35$, and Robots: $t(737.86) = 11.12$, .95 CI [0.94, 1.33], $p < .001$, d = 0.77. Rabbits also elicited higher scores than Robots, $t(952.2) = 7.75$, $p < .001$, .95 CI [0.60, 1.00], d = 0.50.

Disoriented. As with the unnerved scale, there was a significant effect of condition. The mean for Rabbits was once again the highest (M = 2.56, SD = 1.17), followed by Robots (M

=2.18, *SD* = 1.23) and control (*M* = 1.94, *SD* = 1.09). Follow-up tests revealed that Rabbits produced significantly higher scores than control, $t(651.42) = 7.58$, $p < .001$, .95 CI [0.45, 0.79], $d = 0.55$, as did Robots, $t(676.12) = 2.90$, .95 CI [0.08, 0.41], $p < .001$, $d = 0.21$. Rabbits was more disorienting than Robots, $t(951.1) = 4.92$, $p < .001$, .95 CI [0.23, 0.53], $d = 0.32$.

In sum, Study 1 established a measure of uncanny emotions, and high-level cognitions that might accompany uncanniness, that perform well across two distinct elicitors. In follow-up studies, we determined if uncanniness could be differentiated from other candidate emotions (e.g., disgust, fear) and whether the unnerved measure converged with related personality variables that correspond with discomfort and with uncertainty (e.g., personal need for structure, neuroticism). Thus, we conducted Study 2 to establish convergent and discriminant validity.

Study 2

Study 2 included various state and trait measures of related emotions. We also manipulated participants' experience of uncanniness and other emotions by administering one of four videos: an uncanny video, a disgusting video, a fearful video, or a neutral video. We hypothesized that participants who watched the uncanny video would score the highest on the unnerved scale. All materials for this study are pre-registered at https://osf.io/qg6st/?view_only=6a406a6175df438abfa11334977884d2, and we outline the reasons for our analysis plan deviations in the sections below.

A second aim of this study was to determine whether the disoriented scale could be considered a facet of uncanniness, or if it is instead measures a distinct phenomenon. Though on its face, this scale evaluates high-level cognitive reactions to the uncanny, it is possible those reactions are essential to the construct. For example, if feeling disoriented always accompanies uncanniness, whereas fear and disgust do not, we would conclude this is a distinctive quality of

uncanniness. We examined correlations between this and other affect measures to determine if unnerved and disoriented feelings are both uniquely related to uncanniness.

Methods

Participants

Our pre-registered plan was to recruit 900 American Mturkers, anticipating that 100 would fail attention checks (a sample size of 800 participants would allow us to detect small effects with a probability of over 80%). We obtained 917 participants of whom 57 failed both of our attention checks or reported that they did not watch the clip completely, leaving a final sample of 860.

Procedure

After completing some personality measures (see below) participants were randomly assigned to watch a 90 second clip that we selected to be either uncanny, disgusting, fearful, or neutral. The uncanny clip was a shortened version of Rabbits (see Study 1). The fear clip was from "*Scream 2*" and showed a woman pursued by a masked killer. The disgusting clip was from "*Indiana Jones and the Last Crusade"* and showed a seething mass of rats in a cave. The neutral clip was from "*Lost in Translation*" and showed a woman and a man interacting. Past research shows these latter three clips specifically elicit their target emotions without eliciting much of other measured emotions, at levels comparable to what we found in Study 1 (i.e., emotions at or slightly above scale midpoint; Schaefer et al., 2010; Jenkins, 2012).

After watching one of the clips, participants responded to two attention check questions about its content. Then, they completed the unnerved and disoriented scales, where they indicated whether each statement described their feelings right now on a 7-point scale ranging from 1=Not at all to 7=Very much. Next, participants completed our measures of discriminant

and convergent validity (see below) followed by a demographics form, another attention check, and a quality check (indicating whether they watched the entire clip).

Measures

We hypothesized that uncanny emotions would be related to state anxiety, based on past evidence connecting arousal to existential threats (McGregor, Prentice, & Nash, 2013; Jonas et al., 2014) and connecting anxiety to sensitivity to objects believed to fall into the uncanny valley (Bartneck et al., 2009; Ho et al., 2008; MacDorman & Entezari, 2015). We used the State-Trait Anxiety Inventory (STAI; Spielberger et al., 1999) to measure state anxiety.

We also measured personality variables that we hypothesized would correlate positively with sensitivity to uncanniness. We included the Ten Item Personality Inventory (Rammstedt & John, 2007), anticipating that neuroticism would predict feelings of uncanniness (neuroticism predicts evaluating objects as more uncanny; MacDorman & Entezari, 2015). We also administered the Personal Need for Structure scale (PNS; Newberg & Newsom, 1993), and the Behavioral Inhibition Scale (BIS; Carver & White, 1994).

A central goal was to establish that uncanny feelings converge with fear and disgust, but that our scale is specialized for events that elicit uncanniness and not these other negative emotions. To this end, we measured which conditions led to the strongest expressions of unnerved feelings. We developed a two-item disgust measure (i.e., “How disgusted did the video make you feel?”, and “How grossed out did the video make you feel?”), a two-item fear measure (i.e., “How scared did the video make you feel?”, and “How afraid did the video make you feel?”), and a two-item uncanny measure consisting of the labels we gave our factors in Study 1

(i.e., "How unnerved did the video make you feel?", and "How disoriented did the video make you feel?")[1], all responses ranged from 1 = Not at all to 10= Very.

Results and Discussion

Convergence between related constructs

Our pre-registered predictions were that State Anxiety would positively correlate with uncanny emotions, and people higher in neuroticism, PNS, and BIS sensitivity would generally experience more uncanny emotions. To examine these relationships, we investigated responses within the Rabbits condition (see Table 4).

Table 4. Means and correlations between measures.

	Mean (SD)	1	2	3	4	5	6	7
1 Unnerved (α= 0.96)	3.32 (1.76)	-						
2 Disoriented (α= 0.94)	2.58 (1.53)	.740***	-					
3 Neuroticism (α= 0.68)	3.69 (1.39)	.392***	.311***	-				
4 Personal Need for Structure (α= 0.86)	4.21 (1.03)	.033	-.011	.283***	-			
5 Behavioral Inhibition (α= 0.80)	2.98 (0.57)	.225**	.112	.599***	.428**	-		
6 State Anxiety (α= 0.95)	2.69 (0.87)	.732***	.568***	.541***	.126	.194**	-	
7 Fear (α= 0.96)	3.13 (3.01)	.763***	.651***	.255***	.013	.135*	.520***	-
8 Disgust (α= 0.93)	2.36 (2.81)	.532***	.621***	.043	-.089	.051	.265***	.715***

Note. Means and correlations were calculated using only the Rabbits condition.

Focusing on unnerved feelings, the measure of BIS sensitivity was moderately correlated, $r = .225$, $p = .001$, indicating that people who are higher in behavioral inhibition are somewhat more likely to feel unnerved. Neuroticism was also moderately correlated, $r = .392$, $p < .001$, whereas state anxiety was highly correlated, $r = .732$, $p < .001$. This supports the theoretical model we are forwarding; anxiety is highly related to uncanny emotions. Contrary to our expectations, people's need for a structured orderly life (measured by the PNS scale) was not related: $r = .033$, $p = .623$. Past studies have found that the need for structure is relevant to individuals' propensity to assign eeriness to human-like objects (see Lischetzke et al., 2017) so we continued to probe this relationship in follow-up studies.

[1] We present pre-registered analyses using this two-item measure in the SOM Section 2.

Disorientation, fear, and disgust

Replicating Study 1, disoriented feelings correlated strongly with unnerved feelings, $r = .740$, $p < .001$. If this trend generalizes to other forms of uncanny experiences, besides reactions to the Rabbits stimulus, then this would point to disoriented feelings as characteristic of encounters with the uncanny.

On the other hand, the correlation between unnerved and disoriented feelings was comparable in size to correlations between unnerved feelings and other emotions; in particular, fear and disgust. We expected these might converge, and our expectations were confirmed: Fear correlated strongly with unnerved feelings, $r = .763$, $p < .001$, and disgust correlated moderately, $r = .532$, $p < .001$. We draw two conclusions from these trends; first, it is likely that other negative emotions typically accompany uncanniness. Second, disorientation does not necessarily have a uniquely strong relationship to uncanniness, given that fear and disgust are also highly correlated to unnerved emotions.

Effect of Condition

Though fear and disgust seem to accompany uncanniness, a goal of our study was to determine if the unnerved scale can discriminate between different kinds of events: uncanny, fearful, and disgusting ones. We probe this question by comparing the effect of condition on each of these measures. We report our findings using ANOVA with Welsch tests to account for unequal variance, and then evaluate relationships with fear and disgust entered as covariates (see Table 5). Our pre-registered plan was to test dummy-coded variables in a linear regression analysis, so we present the results using this alternate analysis in the SOM Section 2 (the results are the same as what we report below). The SOM also presents pre-registered analyses using disoriented feelings as the dependent measure.

Table 5. Welsch test ANOVA models with and without covariates.

Source	df	Mean square	F	*p*	ηp2	df	Mean square	F	*p*	ηp2
	Without Covariates					With Covariates				
Condition	3	76.18	27.49	<.001	0.09	3	18.51	14.15	<.001	0.03
Fear scale						1	510.78	390.55	<.001	0.30
Disgust scale						1	11.59	8.86	.003	.007
Error	856	2.77				845	1.30			

Table 6. Post-hoc comparisons of conditions with Holm-Bonferroni adjusted p-values.

Source	Mean Difference	t	*p-holm*	Cohen's d	Mean Difference	t	*p-holm*	Cohen's d
	Without Covariates				With Covariates			
Uncanny clip								
vs. fear clip	0.45	2.84	.009	0.27	0.65	6.04	<.001	0.57
vs. disgust clip	0.74	4.70	<.001	0.44	0.55	4.70	<.001	0.48
vs. control clip	1.46	8.87	<.001	0.90	0.48	4.03	<.001	0.42
Fear clip								
Vs. control clip	1.02	6.17	<.001	0.61	-0.18	-1.45	.444	-0.15
Disgust clip								
vs. control clip	0.72	4.36	<.001	0.43	-0.07	-0.60	.784	-0.06

Note. Degrees of freedom for the model without covariates was 856; with covariates 845. Mean differences for models with covariates are based on estimated marginal means.

With and without covariates, the overall ANOVA revealed that participants' condition significantly explained their unnerved emotions. The uncanny Rabbits clip elicited the strongest reactions (without covariates: $M = 3.32$, $SD = 1.76$; estimated marginal mean with covariates: $M = 3.12$, $SE = 0.08$) followed by the fear clip ($M = 2.88$, $SD = 1.80$; estimated marginal mean: $M = 2.47$, $SE = 0.08$) and disgust clip ($M = 2.58$, $SE = 1.76$; estimated marginal mean: $M = 2.57$, $SE = 0.08$). The control clip elicited the weakest reactions ($M = 1.86$, $SE = 0.09$; but estimated marginal mean exceeds fear and disgust: $M = 2.64$, $SE = 0.09$). Follow-up comparisons revealed that participants who watched the uncanny Rabbits clip scored significantly higher on unnerved feelings than those who watched the fear clip, and those who watched the disgust clip (Table 6).

Confirmatory Factor Analysis

Another aim of Study 2 was to evaluate model fit among participants in the experimental condition. Using the R package lavaan, we used maximum likelihood estimation to analyze the factor structure. Our pre-registered plan was to make a holistic evaluation of the four fit indices: The chi-square statistic, the RMSEA, SRMR, and the CFI. Our original plan was to present

analyses using the two-factor version, which is available in the SOM, but for theoretical reasons we focus here on the single factor version.

Using only scores from participants in the Rabbits condition, the RMSEA was higher than the cut-off of .08 (.108) suggesting that the model does not have acceptable fit to the data, .90 CI [.082, .136]. Chi-square was $\chi^2(20, N = 226) = 72.943$, $p < .001$, $\chi^2/df = 3.65$. The chi-square test is sensitive to sample size (Bagozzi & Yi, 1988; Kline, 2005) whereas the less-sensitive relative chi-square also exceeds guidelines for acceptable fit (see Kline, 2005; Schermelleh-Engel, Moosbrugger, & Müller, 2003).

Other fit indices were more optimistic: The CFI was .972, which exceeds even the conservative cut-off of .950. Standardized Root Mean Square Residual (SRMR) was below the cut-off of 0.080 (0.023) suggesting good fit. Model fit was not meaningfully different when we tested among all 860 participants; we report the full results of this pre-registered analysis in the SOM Section 3.

Table 7. Item loadings for the two-factor structure.

	Factor Loadings
I feel creeped out	.858
I am uncomfortable	.864
I am unsettled	.898
I have an eerie sensation	.890
I feel freaked out	.880
I am uneasy	.877
I feel very disturbed	.835
I feel weird	.869

We were concerned given that the RMSEA was not acceptable. In follow-up studies, we considered a few possibilities; the first is that our sample was too small at $N = 226$ in the experimental condition, and the second is that our stimulus was shorter than in Study 1 (90 seconds vs. three minutes). We attempted a third confirmatory study ($N = 446$) reported in full in the SOM, using just the three-minute version of the Rabbits clip. Materials and analyses are pre-

registered at https://osf.io/wahfe/?view_only=c846327e64de44618ba6497636a91410[2]. This study showed a slightly improved RMSEA, though it was still high at .097, .90 CI [.079, .116], whereas other indices suggested the model was well-fitting: CFI (.976) and SRMR (0.021). The Chi Square test showed similar model fit to Study 2, $\chi^2(20, N = 446) = 103.835$, $p < .001$, $\chi^2/df = 5.19$. We continued to evaluate the fit statistics for our measure in Study 3.

Thus far, we have tested unnerved feelings by presenting participants with uncanny visual and auditory clips. But this leaves open questions of what other experiences can elicit uncanniness; besides human-like androids and surreal film clips, it is unclear what naturalistic source of uncanniness would lead to feelings captured in our scale. We were particularly interested in if a global pandemic caused unnerved emotions. We hypothesized that the 2020 coronavirus pandemic was a surreal, world-changing event that unnerved and violated expectations.

Study 3

We replicated the procedure from Study 1, using both an uncanny and neutral stimulus to determine, first, if world-changing events cause unnerved feelings, and second, if people's experience of the pandemic interacts with how they perceive other uncanny stimuli.

Uncanniness in world events

If the uncontrollable or unexpected can create unease, and the once-familiar unfamiliar is traditionally uncanny, can threatening world events be uncanny? The 2020 coronavirus pandemic caused many profound and irrevocable changes in people's lives. The virus affected every aspect of life; economic, political, (Long & Van Dam, 2020; Cassidy, 2020), and individual, as people struggled to regain a sense of order and routine (Simon, 2020).

[2] As in Study 2, we pre-registered the two-factor scale, with unnerved and disoriented facets. In the SOM, we report model fit for this scale as well.

During this time, uncertainty may have reached an all-time high. Indeed, the World Uncertainty Index (WUI), which assesses how often "uncertainty" and its variants appear in country reports, reached its highest level during the first quarter of 2020 (World Uncertainty Index, 2021). The empty streets had an eerie atmosphere (Coleman & Brian, 2020; McKenzie, 2020; Elliott, 2020) and people were comfortable describing other pandemic experiences as surreal; the lack of strong leadership and disruption in routine was described as Kafkaesque, surreal and strange (Simon, 2020; Chuck, 2020). In our own lab, we found that Google searches on the terms "surreal" and "eerie" corresponded with searches on "pandemic", "COVID-19", and "coronavirus". The time series data was highly correlated, $r = .760$. The full results of this analysis are in the SOM Section 4.

We administered our uncanny measure to novel American Mturk participants; half viewed the same neutral clip used throughout, and half viewed the life-like humanoid subjects from Study 1. We hypothesized that participants assigned to the control condition would feel more unnerved than those who were exposed to the neutral video we used during Study 1. We had no expectations about the experimental condition, but we sketched out two possibilities: Either the pandemic would cause relatively more unnerved feelings in the experimental condition, or the experimental stimulus would overwhelm any effects of the pandemic, leading to similar uncanny feelings as in Study 1.

Methods

We collected the data on April 9, 2020, near the first peak of daily confirmed cases of COVID-19 in the US: 2,120 deaths were reported on this particular day (World Health Organization, 2020). Cumulatively, American cases had exceeded 500,000, with 22,500 deaths by this time (John Hopkins, 2020). All US states had closures and lock-down procedures at

various levels of severity. America experienced an unprecedented spike in depression, stress, and anxiety (Wan, 2020). Unemployment was extreme, and relief was uncertain (Cohen & Hsu, 2020). The effects and long-term consequences of COVID-19 remained mysterious, and the virus was spreading rapidly. We compared mean levels of uncanniness to Study 1, which in contrast to Study 3 was conducted on November 26, 2018.

Participants

Aiming for an item-subject ratio of at least 1:10, we recruited 519 participants from Mturk. As in our previous studies, we excluded participants who failed both attention checks and / or reported that they did not watch the clip completely. We excluded 48 participants, leaving 471 participants.

Procedure

Participants were randomly assigned to see either the neutral video or the video of humanoid robots from Study 1. They then completed the unnerved measure, and measures of fear and disgust, state anxiety, neuroticism, BIS, and PNS, consistent with Study 2. Participants also completed a novel measure of COVID-19 preoccupation, consisting of 10 items evaluating thoughts and emotions about the pandemic (e.g., “The COVID-19 scare has caused me to feel lonely”; 1=strongly disagree, 7=strongly agree; see the SOM Section 4 for the full scale). We included exploratory measures associated with other projects, all available on the OSF at https://osf.io/gckas/?view_only=b1cb7332dce3411abb2c3d80ecedc8a7.

Results and Discussion

Replicating Study 2 relationships to similar constructs

As in Study 2, we investigated relationships between our unnerved measure and convergent constructs: state anxiety, neuroticism, PNS, and BIS sensitivity. This time we

suspected control participants would be feeling uncanny, so we evaluated correlations across both conditions (see Table 8).

Table 8. Means and correlations between measures.

		Mean (SD)	1	2	3	4	5	6	7	8
1	Pandemic Preoccupation (α = .88)	4.46 (1.30)	-							
2	Unnerved (α= 0.97)	2.88 (1.84)	.482***	-						
3	Disoriented (α = 0.96)	2.59 (1.74)	.455***	.833***	-					
4	Neuroticism (α = 0.63)	3.39 (1.40)	.324***	.339***	.346***	-				
5	Personal Need for Structure (α = 0.81)	4.26 (0.91)	.143**	-.002	-.072	.153**	-			
6	Behavioral Inhibition (α = 0.73)	3.84 (1.10)	.369***	.130**	.014	.427***	.499***	-		
7	State Anxiety (α = 0.93)	2.47 (0.82)	.500***	.655***	.583***	.483***	.003	.254***	-	
8	Fear (α = 0.95)	2.82 (3.05)	.483***	.766***	.725***	.325***	.012	.085	.652***	-
9	Disgust (α = 0.93)	2.40 (2.95)	.393***	.789***	.774***	.260***	-.044	-.006	.541***	.806***

Note. Means and correlations were calculated using both conditions.

As in Study 2, neuroticism was moderately positively correlated with our scale, $r = .339$, $p < .001$, and state anxiety was strongly correlated, $r = .655$, $p < .001$. Once again, PNS did correlate with unnerved feelings: $r = -.002$, $p = .973$. BIS sensitivity positively correlated, but the relationship was attenuated from Study 1 ($r = .130$, $p = .006$). Fear and disgust remained strongly positively correlated with unnerved feelings (fear: $r = .766$, $p < .001$; disgust: $r = .789$, $p < .001$).

Pandemic preoccupation

Our novel scale of pandemic preoccupation had a moderate relationship with unnerved feelings ($r = .483$, $p < .001$), as well as fear ($r = .483$, $p < .001$), disgust ($r = .393$, $p < .001$), state anxiety ($r = .500$), and our novel test of disoriented feelings ($r = .455$, $p < .001$). Therefore, the pandemic likely caused a shift in uncanniness, and other negative valence emotions, though this correlational evidence is not definitive. To probe this, we compared participants' mean level uncanniness in Study 3 to past studies.

Comparing the effects of the pandemic to past studies

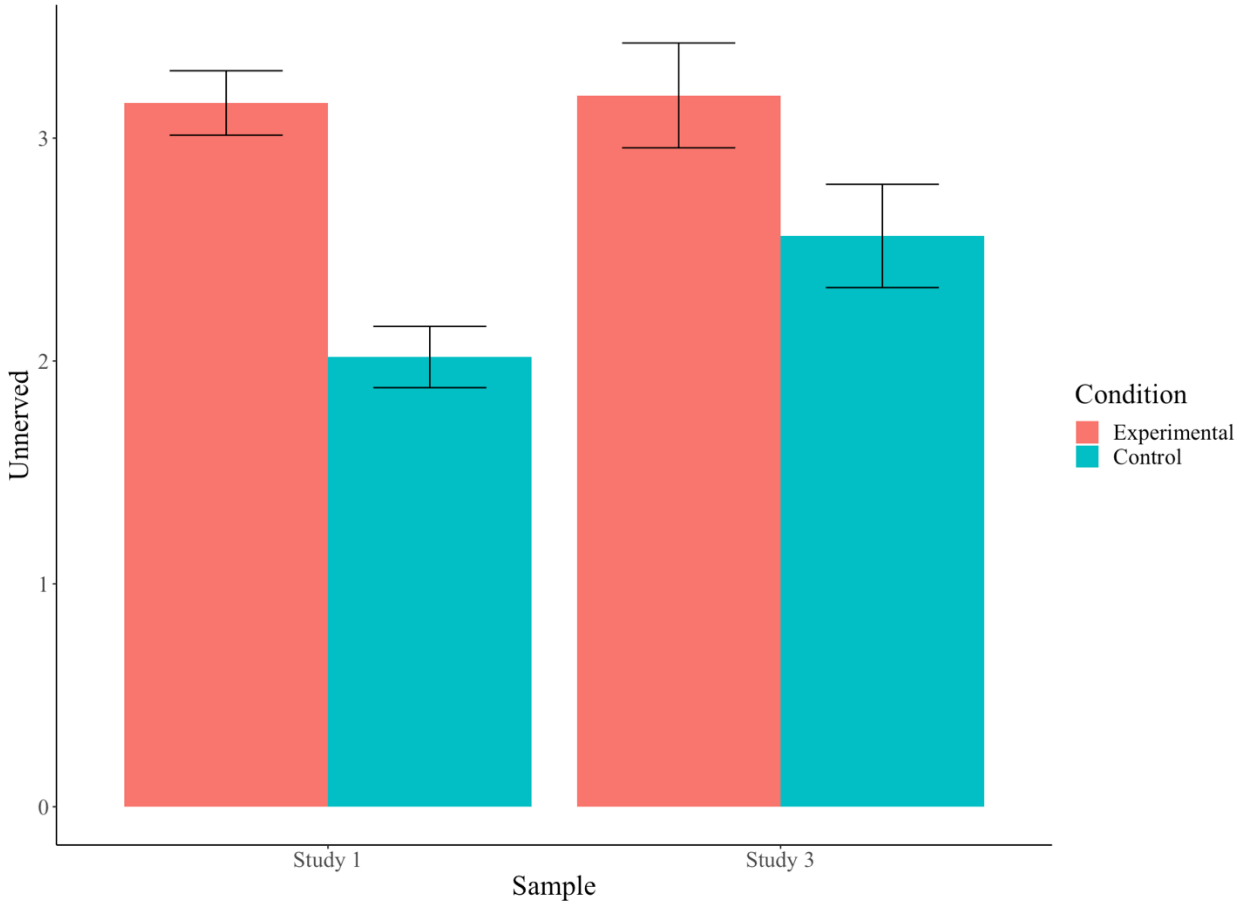
We compared Study 3 to Study 1's control and experimental conditions, yielding a combined sample size of $N = 1249$. We tested our hypotheses using ANOVA (see Table 9).

Table 9. Unnerved feelings by Condition in Studies 1 and 3

Source	df	Mean square	F	*p*	η_p^2
Condition	1	223.77	86.13	<.001	0.060
Sample (Study 1 vs. 3)	1	23.77	9.15	.003	0.007
Condition × sample	1	18.51	7.13	.008	0.005
Error	1235	2.60			

Responses to our scale changed from Study 1 to Study 3: there was a significant main effect of condition qualified by a significant interaction between sample and condition. Among those who watched the control video, those who watched it during the pandemic felt significantly more unnerved (Study 3 $M = 2.56$, $SD = 1.78$; Study 1 $M = 1.20$, $SD = 1.20$), $t(525) = 3.97$, $p < .001$, .95 CI [0.19, 0.54], $d = 0.36$. In the experimental condition, participants felt similar across both studies (Study 3 $M = 3.19$, $SD = 1.84$; Study 1 $M = 3.16$, $SD = 1.61$), $t(710) = 0.2$, $p = .994$, .95 CI [-0.14, 0.18], $d = 0.02$, suggesting that the uncanny Robots video overwhelmed unnerved emotions that resulted from the pandemic (see Table 8 and Figure 3).

Figure 3. Comparing control and experimental conditions in Studies 1 and 3.



Note. Error bars represent 95% Confidence Intervals.

Study 3 Confirmatory Factor Analysis

We evaluated model fit using maximum likelihood, testing responses within both conditions (see loadings in the SOM Section 4). The RMSEA was higher than cut-off, consistent with what we report in Study 3, .095, .90 CI (.077, .095), $p < .001$, $\chi^2(20, N = 471) = 104.262$, $p < .001$, $\chi^2/df = 5.21$. Also consistent, the CFI (.982) and SRMR (.015) suggested good fit. We also evaluated the statistics when we measured responses from those in the experimental condition, which showed acceptable model fit according to the RMSEA: .060, .90 CI (.028, .090), $p = .267$, and CFI (.992) as well as the SRMR (.013). Chi square was also smaller at $\chi^2(20, N = 238) = 37.08$, $p = .011$, $\chi^2/df = 1.85$. This improved fit suggests that the Robots clip elicits a

purer unnerved experience than the Rabbits video, or than the global pandemic, both of which might also implicate more of other related emotions.

General Discussion

These studies defined and tested uncanniness, a concept that eluded early psychoanalysts and continues to confound artists and engineers to this day. We developed a scale measuring uncanny feelings, determined whether it can differentiate between uncanniness and related affective experiences (fear, disgust), and evaluated its capacity to probe unnerving circumstances in people's lives during the 2020 coronavirus pandemic.

Theoretical Contributions

Our studies broaden the scope of uncanniness research, integrating psychoanalytic conceptualizations of the construct (Freud, 1919/2003; Jenstch, 1906) with modern psychological perspectives. We follow in the tradition of past research findings that uncanniness is not limited to encounters with human-like robots (Ramey, 2005), and even uncanny concepts, like a robot that possesses a human mind, can elicit eerie emotions (Gray & Wegner, 2012). We add that a wider array of expectancy violating events can elicit uncanny emotions, from human-like robots, to surreal films, to a worldview-threatening global pandemic.

Our measure is the first of its kind, a validated scale that is sensitive to people's affective reactions to expectancy-violating events. Past measurement attempts either focus on the aesthetic qualities of target objects (e.g., MacDorman & Ishiguro, 2010, 2015) or employ a limited range of affective terms to probe uncanniness. We developed a reliable measure tracking unnerved feelings from encounters with the uncanny. We also established traits that make people more sensitive to the uncanny: neuroticism and BIS sensitivity. This finding adds evidence that individual differences predict sensitivities to uncanniness (see Bartneck et al., 2009; Ho et al.,

2008; MacDorman & Entezari, 2015) and suggests that people might have different reactions to expectancy violations. For example, a global pandemic, economic crash, or shifting political powers, might feel unnerving to some, and more routine to others.

Our scale can be used to determine if uncanniness explains people's reactions to reminders of death. A possible source of uncanniness is that human-like robots bring to the forefront thoughts of one's own mortality (MacDorman & Ishiguro, 2006). A well-documented response to mortality salience is that people affirm their worldviews (for meta-analyses, see Burke, Martens, & Faucher, 2010, Chen et al., 2022). Though affect change does not appear to explain these reactions (Pyszczynski, Greenberg, & Solomon, 1999; Pyszczynski, Solom, & Greenberg, 2015) it is possible that previous research measured the wrong kind of affect. Our scale is sensitive to emotions driven by surreal and expectancy-violating events, and might be informative of what proximally explains or predicts reactions to existential threats.

In addition to unnerved emotions, throughout we measured disoriented feelings following exposure to the uncanny. On its face, the disoriented scale is reminiscent of Freud's (1919) account of the uncanny; lacking control, and experiencing a sense of repetition, after encountering something once familiar made unfamiliar. This scale tracked high-level reactions to uncanniness, rather than emotion change, and was only slightly more correlated with unnerved feelings than fear or disgust. Though we did not include it as a facet of our measure, we report our findings on this measure in the SOM, which may be useful for future research exploring potentially disturbing or horrific consequences of uncanniness.

Unanswered Questions

An unanswered question from this research is whether some specific quality of uncanny objects drives these effects more than others. Though we define uncanniness generally as

unnerved feelings, the greatest cause of these feelings is still undetermined. Our paper does not probe any specific hypothesis about the origin of the uncanny valley, such as whether uncanny feelings stem from the inability to categorize a stimulus (category uncertainty hypothesis; Yamada et al., 2013) of from the perception of mismatched features or qualities of a stimulus (perceptual mismatch theory; Kätsyri et al., 2015; Wang et al., 2015), or from the attribution of minds and experience to objects (Gray & Wegner, 2012). We did not select stimuli that isolate these mechanisms, and therefore do not know which (if any) of these expectancy-violating experiences are responsible for eliciting the most unnerved feelings.

Uncovering all routes to uncanniness will enable researchers to mitigate potential discomfort with new technologies. Virtual reality (VR), projected to grow in popularity worldwide (Statista, 2021), can elicit uncanniness through multiple routes. Stein and Ohler (2017) determined in a VR setting that people felt eerier when interacting with self-directed computer-controlled chatbots, as opposed to scripted chatbots, whereas the bot's human likeness did not predict uncanniness. This speaks to *conceptual* sources of uncanniness associated with VR, whereas other studies find that *perceptual* elements matter as animated chatbots are eerier than simpler text bots (Ciechanowski, Przegalinska, Magnuski, & Gloor, 2019). We add that the novelty of the VR environment may itself be a source of uncanniness, separate from the qualities of one's discussion partner. Immersing oneself in a digital space could also be unnerving, and future research should consider this variable and as a route to the uncanny.

Different routes to uncanniness may also implicate different functional systems, and different developmental trajectories. A recent study finds that children are sensitive to human-like avatar faces at 12 months of age, just as they become more expert at perceiving human faces (Lewkowicz & Ghazanfar, 2012). Perceptual narrowing is key to perceiving uncanny faces, but it

is unclear how and when other sensitivities to uncanniness emerge, like perceiving machines with minds as eerie (see Gray & Wegner, 2012). It remains a question for future research to determine when people become sensitive to uncanny concepts, like robots with experience, or uncanny situations, like life-disrupting world events. Culture, and beliefs about human uniqueness might also affect sensitivity to the uncanny.

Limitations

Our studies have several limitations. First, we find compelling evidence that fear and disgust are linked to unnerved feelings, though we went to lengths to disentangle them. High correlations to fear and disgust lead us to question whether basic emotions account for much of the uncanny experience (see Ekman, 1992, 1999). We see this as consistent with how uncanniness presents itself in popular media, and with how the horror genre often makes simultaneous use of fearful, disgusting, and uncanny elements. Still, our studies are limited in the range of stimuli we used to elicit uncanniness. Future research should test a larger range of stimuli, which may help disentangle uncanniness from these related emotions.

Second, though we find evidence that various stimuli and settings elicit uncanny emotions, the manipulations were still somewhat weak. Participants responded below the scale midpoint in all three studies. A stronger stimulus may reveal something new about the construct. For example, coming face-to-face with a lifelike robot might elicit a new brand of strangeness not captured by our measure. How this scale performs with even stronger stimuli remains an open question.

Third, though our manipulations may have been weaker than some candidate experiences, it is worth noting that they may also have been too strong, or salient; anomalies can affect behaviour even outside of conscious awareness (Proulx & Heine, 2008; Randles et al.,

2011; 2018) yet we suspect participants were consciously aware of the strangeness of our manipulations, and likely attributed their feelings to those situations. Our experiments do not establish whether surreal experiences must be consciously accessible to cause uncanny feelings.

Conclusions

Our scale measures unnerved emotions that accompany encounters with the uncanny. We find evidence that a broad range of events activates these emotions, from perceiving human-like robots to enduring a life-altering global pandemic. From early psychoanalytic accounts of the familiar-unfamiliar to recent brushes with disturbing humanoids (Mori, 1970; Tinwell et al., 2011), the uncanny has been a topic of interest for over 100 years. Now we are beginning to understand what this feeling is like.

References

Appel, M., Izydorczyk, D., Weber, S., Mara, M., & Lischetzke, T. (2020). The uncanny of mind in a machine: Humanoid robots as tools, agents, and experiencers. *Computers in Human Behavior*, *102*(July 2019), 274–286. https://doi.org/10.1016/j.chb.2019.07.031

Bagozzi, R. P., & Yi, Y. (1988). On the evaluation of structural equation models. *Journal of the academy of marketing science*, *16*(1), 74-94.

Bartneck, C., Kulić, D., Croft, E., & Zoghbi, S. (2009). Measurement instruments for the anthropomorphism, animacy, likeability, perceived intelligence, and perceived safety of robots. *International journal of social robotics*, 1(1), 71-81.

Breton, A. (1924). First surrealist manifesto. *Surrealism. McGraw-Hill, New York*, 66–75.

Brink, K. A., Gray, K., & Wellman, H. M. (2019). Creepiness Creeps In: Uncanny Valley Feelings Are Acquired in Childhood. *Child Development*, *90*(4), 1202–1214.

Burke, B. L., Martens, A., & Faucher, E. H. (2010). Two decades of terror management theory: A meta-analysis of mortality salience research. *Personality and Social Psychology Review*, 14(2), 155-195.

Burleigh, T. J., & Schoenherr, J. R. (2015). A reappraisal of the uncanny valley: categorical perception or frequency-based sensitization?. *Frontiers in Psychology*, 5, 1488.

Burleigh, T. J., Schoenherr, J. R., & Lacroix, G. L. (2013). Does the uncanny valley exist? An empirical test of the relationship between eeriness and the human likeness of digitally created faces. *Computers in Human Behavior*, 29(3), 759-771.

Cheetham, M., Wu, L., Pauli, P., & Jancke, L. (2015). Arousal, valence, and the uncanny valley: psychophysiological and self-report findings. *Frontiers in Psychology*, 6(6), 1–15.

Chen, L., Benjamin, R., Lai, A., & Heine, S. (2022). Managing the terror of publication bias: A

comprehensive p-curve analysis of the Terror Management Theory literature. https://doi.org/10.31234/osf.io/kuhy6

Ciechanowski, L., Przegalinska, A., Magnuski, M., & Gloor, P. (2019). In the shades of the uncanny valley: An experimental study of human–chatbot interaction. *Future Generation Computer Systems*, *92*, 539–548.

Carver, C. S., & White, T. L. (1994). Behavioral inhibition, behavioral activation, and affective responses to impending reward and punishment: The BIS/BAS Scales. *Journal of Personality and Social Psychology*, *67*(2), 319–333.

Cassidy, J. (2020, April 3). The Coronavirus Is Transforming Politics and Economics. Retrieved July 10, 2020, from https://www.newyorker.com/news/our-columnists/the-coronavirus-is-transforming-politics-and-economics

Cheetham, M., Suter, P., & Jäncke, L. (2011). The human likeness dimension of the "uncanny valley hypothesis": behavioral and functional MRI findings. *Frontiers in human neuroscience*, 5, 126.

Chuck, E. (2020, March 11). American on coronavirus lockdown in Italy: 'It's surreal. It's dystopian.' Retrieved July 09, 2020, from https://www.nbcnews.com/health/health-news/american-coronavirus-lockdown-italy-it-s-surreal-it-s-dystopian-n1155576

Coleman, C., & Brian, M. (2020, March 10). The eerie emptiness in a world facing the coronavirus. Retrieved July 09, 2020, from https://www.washingtonpost.com/graphics/world/2020/03/10/eerie-emptiness-world-facing-coronavirus/

Courtney, E. P., Goldenberg, J. L., & Boyd, P. (2020). The contagion of mortality: A terror management health model for pandemics. *British Journal of Social Psychology*, *59*(3), 607–

617.

COVID-19 United States Cases by Country (April, 2020). *Johns Hopkins University*. Retrieved from https://coronavirus.jhu.edu/us-map

Crowell, C. R., Deska, J. C., Villano, M., Zenk, J., & Roddy Jr, J. T. (2019). Anthropomorphism of Robots: Study of Appearance and Agency. *JMIR Human Factors*, *6*(2).

Dinno, A. (2009). Implementing Horn's parallel analysis for principal component analysis and factor analysis. *The Stata Journal*, 9(2), 291-298.

Diel, A., Weigelt, S., & Macdorman, K. F. (2022). A meta-analysis of the uncanny valley's independent and dependent variables. *ACM Transactions on Human–Robot Interaction*, *11*(1).

Elliot, J. K. (2020, March 19). World without crowds: Eerie photos of empty cities in coronavirus lockdown. Retrieved July 09, 2020, from https://globalnews.ca/news/6701779/empty-city-photos-coronavirus/

Ekman, P. (1992). An argument for basic emotions. *Cognition and Emotion*, *6*(3-4), 169.

Freud, S. (2003). *The uncanny*. Penguin.

Geller, T. (2009). Overcoming the uncanny valley. *IEEE Computer Graphics and Applications*, *28*(4), 11–17.

Goldenberg, J. L., Pyszczynski, T., Greenberg, J., Solomon, S., Kluck, B., & Cornwell, R. (2001). I am not an animal: mortality salience, disgust, and the denial of human creatureliness. *Journal of Experimental Psychology. General*, *130*(3), 427–435.

Gray, J. A., & McNaughton, N. (2000). *The neuropsychology of anxiety: An enquiry into the functions of the septo-hippocampal system* (2nd ed.). Oxford: Oxford University Press.

Gray, H. M., Gray, K., & Wegner, D. M. (2007). Dimensions of mind perception. *Science*,

315(5812), 619.

Gray, K., & Wegner, D. M. (2012). Feeling robots and human zombies: Mind perception and the uncanny valley. *Cognition, 125*(1), 125–130.

Greenberg, J., Pyszczynski, T., & Solomon, S. (1986). The Causes and Consequences of a Need for Self-Esteem: A Terror Management Theory. In R. F. Baumeister (Ed.), *Public Self and Private Self* (pp. 189–212).

Ho, C. C., & MacDorman, K. F. (2010). Revisiting the uncanny valley theory: Developing and validating an alternative to the Godspeed indices. *Computers in Human Behavior, 26*(6), 1508–1518.

Ho, C. C., & MacDorman, K. F. (2017). Measuring the uncanny valley effect. *International Journal of Social Robotics*, 9(1), 129-139.

Jonas, E., McGregor, I., Klackl, J., Agroskin, D., Fritsche, I., Holbrook, C., … Quirin, M. (2014). Threat and Defense. From Anxiety to Approach. In *Advances in Experimental Social Psychology* (Vol. 49).

McKenzie, S. (2020, April 28). Coronavirus: 'Eerie' atmosphere on an island without tourists. Retrieved July 09, 2020, from https://www.bbc.com/news/uk-scotland-highlands-islands-52415316

McNaughton, N., & Corr, P. J. (2004). A two-dimensional neuropsychology of defense: Fear/anxiety and defensive distance. *Neuroscience and Biobehavioral Review*, 28(3), 285–305.

Hanson, D. (2005). Expanding the Aesthetic Possibilities for Humanoid Robots. *IEEE-RAS International Conference on Humanoid Robots*, 24–31.

Heidegger, M. (1927/1962). *Being and Time*. New York, NY: State University of New York

Press.

Heine, S. J., Proulx, T., & Vohs, K. D. (2006). The Meaning Maintenance Model: On the Coherence of Social Motivations. *Personality and Social Psychology Review*, *10*(2), 88–110.

Ho, C.-C., & MacDorman, K. F. (2010). Revisiting the uncanny valley theory: Developing and validating an alternative to the Godspeed indices. *Computers in Human Behavior*, *26*(6), 1508–1518.

Ho, C.-C., MacDorman, K. F., & Pramono, Z. A. D. D. (2008). Human emotion and the uncanny valley. *Proceedings of the 3rd International Conference on Human Robot Interaction - HRI '08*, 169.

Holbrook, C., Sousa, P., & Hahn-Holbrook, J. (2011). Unconscious vigilance: Worldview defense without adaptations for terror, coalition, or uncertainty management. *Journal of personality and social psychology*, 101(3), 451.

Horn, J. L. (1965). A rationale and test for the number of factors in factor analysis. *Psychometrika*, *30*(2), 179–185.

Jenkins, L. M., & Andrewes, D. G. (2012). A New Set of Standardised Verbal and Non-verbal Contemporary Film Stimuli for the Elicitation of Emotions. *Brain Impairment*, *13*(2), 212–227.

Jentsch, E. (1906). *Zur psychologie des unheimlichen*.

Jonas, E., McGregor, I., Klackl, J., Agroskin, D., Fritsche, I., Holbrook, C., ... & Quirin, M. (2014). Threat and defense: From anxiety to approach. *In Advances in experimental social psychology* (Vol. 49, pp. 219-286). Academic Press.

Kätsyri, J., Förger, K., Mäkäräinen, M., & Takala, T. (2015). A review of empirical evidence on

different uncanny valley hypotheses: Support for perceptual mismatch as one road to the valley of eeriness. *Frontiers in Psychology*, *6*(MAR), 1–16.

Kline, R. B. (2005). *Principles and practice of structural equation modeling. Guilford publications.*

Langer, M., & König, C. J. (2018). Introducing and testing the creepiness of situation scale (CRoSS). *Frontiers in Psychology*, *2220.*

Lewkowicz, D. J., & Ghazanfar, A. A. (2012). The development of the uncanny valley in infants. *Developmental Psychobiology*, *54*(2), 124–132.

Lischetzke, T., Izydorczyk, D., Hüller, C., & Appel, M. (2017). The topography of the uncanny valley and individuals' need for structure: A nonlinear mixed effects analysis. *Journal of Research in Personality*, 68, 96-113.

Long, H., & Van Dam, A. (2020, May 8). Washington Post: Breaking News, World, US, DC News & Analysis. Retrieved July 10, 2020, from https://www.washingtonpost.com/

Lynch, D. (Writer, Director). (2002). *Rabbits* [Film]. United States.

MacDorman, K.F. (2005). Mortality salience and the uncanny valley. In *5th IEEE-RAS International Conference on Humanoid Robots, 2005*. (pp. 399-405). IEEE.

MacDorman, K. F., & Chattopadhyay, D. (2016). Reducing consistency in human realism increases the uncanny valley effect; increasing category uncertainty does not. *Cognition*, *146*, 190–205.

MacDorman, K. F., & Entezari, S. O. (2015). Individual differences predict sensitivity to the uncanny valley. *Interaction Studies*, 16(2), 141-172.

MacDorman, K. F, & Ishiguro, H. (2006). The uncanny advantage of using androids in cognitive and social science research. *Interaction Studies: Social Behaviour and Communication in*

Biological and Artificial Systems, *7*(3), 297–337.

McGregor, I., Prentice, M., & Nash, K. (2013). Anxious Uncertainty and Reactive Approach Motivation (RAM) for Religious, Idealistic, and Lifestyle Extremes: Motivational Conflict and RAM. *Journal of Social Issues*, *69*(3), 537–563.

McGregor, I., Nash, K., Mann, N., & Phills, C. E. (2010). Anxious uncertainty and reactive approach motivation (RAM). *Journal of personality and social psychology*, 99(1), 133.

Mitchell, W. J., Szerszen, K. A., Lu, A. S., Schermerhorn, P. W., Scheutz, M., Macdorman, K. F., & MacDorman, K. F. (2011). A mismatch in the human realism of face and voice produces an uncanny valley. *I-Perception*, *2*(1), 10–12.

Moore, R. K. (2012). A Bayesian explanation of the "Uncanny Valley" effect and related psychological phenomena. *Scientific Reports*, *2*, 864.

Mori, M., & MacDorman, K. (1970). The uncanny valley. *Energy*.

Proulx, T., Heine, S. J., & Vohs, K. D. (2010). When Is the Unfamiliar the Uncanny? Meaning Affirmation After Exposure to Absurdist Literature, Humor, and Art. *Personality and Social Psychology Bulletin*, *36*(6), 817–829.

Proulx, T., & Inzlicht, M. (2012). The Five "A"s of Meaning Maintenance: Finding Meaning in the Theories of Sense-Making. *Psychological Inquiry*, *23*(4), 317–335.

Pyszczynski, T., Greenberg, J., & Solomon, S. (1999). A dual-process model of defense against conscious and unconscious death-related thoughts: an extension of terror management theory. *Psychological review*, 106(4), 835.

Pyszczynski, T., Solomon, S., & Greenberg, J. (2015). Thirty Years of Terror Management Theory: From Genesis to Revelation. In *Advances in Experimental Social Psychology* (1st ed., Vol. 52).

Ramey, C. H. (2006). An inventory of reported characteristics for home computers, robots, and human beings: Applications for android science and the uncanny valley. In *Proceedings of the ICCS/CogSci-2006 Long Symposium 'Toward Social Mechanisms of Android Science', Vancou- ver, Canada*

Ramey, C. H. (2005). The uncanny valley of similarities concerning abortion, baldness, heaps of sand, and humanlike robots. In *IEEE-RAS international conference on humanoid robots*. Tsukuba, Japan.

Rammstedt, B., & John, O. P. (2007). Measuring personality in one minute or less: A 10-item short version of the Big Five Inventory in English and German. *Journal of research in Personality*, 41(1), 203-212.

Randles, D., Heine, S. J., & Santos, N. (2013). The Common Pain of Surrealism and Death: Acetaminophen Reduces Compensatory Affirmation Following Meaning Threats. *Psychological Science*, *24*(6), 966–973.

Randles, D., Proulx, T., & Heine, S. J. (2011). Turn-frogs and careful-sweaters: Non-conscious perception of incongruous word pairings provokes fluid compensation. *Journal of Experimental Social Psychology*, *47*(1), 246–249.

Rivera, J. (2019, July 11).*The lion king review: out of the uncanny valley*. GQ. Retrieved from https://www.gq.com/story/the-lion-king-review

Rozin, P., & Fallon, A. E. (1987). A perspective on disgust. *Psychological Review*, *94*(1), 23.

Schaefer, A., Nils, F., Sanchez, X., & Philippot, P. (2010). Assessing the effectiveness of a large database of emotion-eliciting films: A new tool for emotion researchers. *Cognition & Emotion*, *24*(7), 1153–1172.

Schein, C., & Gray, K. (2015). The eyes are the window to the uncanny valley. *Interaction*

Studies. Social Behaviour and Communication in Biological and Artificial Systems, *16*(2), 173–179.

Schermelleh-Engel, K., Moosbrugger, H., & Müller, H. (2003). Evaluating the fit of structural equation models: Tests of significance and descriptive goodness-of-fit measures. *MPR-Online*, *8*(2), 23–74.

Seyama, J., & Nagayama, R. S. (2007). The uncanny valley: Effect of realism on the impression of artificial human faces. *Presence: Teleoperators and Virtual Environments*, *16*(4), 337–351.

Simon, M. (2020, March 31). Why Life During a Pandemic Feels So Surreal. Retrieved July 09, 2020, from https://www.wired.com/story/why-life-during-a-pandemic-feels-so-surreal/

Spielberger, C. D., Sydeman, S. J., Owen, A. E., & Marsh, B. J. (1999). *Measuring anxiety and anger with the State-Trait Anxiety Inventory (STAI) and the State-Trait Anger Expression Inventory (STAXI).*

Starkey, S., Zemeckis, Goetzman, G., & Teitler, W. (Producers), & Zemeckis, R. (Director). (2004). *The Polar Express* [Motion Picture]. United States: Warner Bros. Pictures.

Statista. (2021, August). Virtual reality (VR) - statistics & facts. Retrieved from https://www.statista.com/topics/2532/virtual-reality-vr/

Stein, J. P., & Ohler, P. (2017). Venturing into the uncanny valley of mind—The influence of mind attribution on the acceptance of human-like characters in a virtual reality setting. *Cognition*, *160*, 43–50.

Tinwell, A., Grimshaw, M., Nabi, D. A., & Williams, A. (2011). Facial expression of emotion and perception of the Uncanny Valley in virtual characters. *Computers in Human Behavior*, *27*(2), 741–749.

Tinwell, A., Nabi, D. A., & Charlton, J. P. (2013). Perception of psychopathy and the Uncanny Valley in virtual characters. *Computers in Human Behavior*, *29*(4), 1617-1625.

Wan, W. (2020, May 4). The coronavirus pandemic is pushing America into a mental health crisis. *Washington Post*. https://www.washingtonpost.com/health/2020/05/04/mental-health-coronavirus/

Wang, S., Lilienfeld, S. O., & Rochat, P. (2015). The Uncanny Valley: Existence and Explanations. *Review of General Psychology*, *19*(4).

Wang, S., & Rochat, P. (2017). Human perception of animacy in light of the uncanny valley phenomenon. *Perception*, 46(12), 1386-1411.

Weis, P. P., & Wiese, E. (2017). Cognitive conflict as possible origin of the uncanny valley. *Proceedings of the Human Factors and Ergonomics Society*, *2017-Octob*, 1599–1603.

World Health Organization. (2020, April 10). *WHO Coronavirus Disease (COVID-19) Dashboard.* Retrieved from https://covid19.who.int/.

Yam, K. C., Bigman, Y., & Gray, K. (2021). Reducing the uncanny valley by dehumanizing humanoid robots. *Computers in Human Behavior*, 125(June), 106945.

Yamada, Y., Kawabe, T., & Ihaya, K. (2013). Categorization difficulty is associated with negative evaluation in the “uncanny valley” phenomenon. *Japanese Psychological Research*, *55*(1), 20–32.

Zlotowski, J. A., Sumioka, H., Nishio, S., Glas, D. F., Bartneck, C., & Ishiguro, H. (2015). Persistence of the uncanny valley: the influence of repeated interactions and a robot's attitude on its perception. *Frontiers in psychology*, 6, 883.