



## Hypothesis: Compulsive hoarding as an atavism

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### ABSTRACT

In this hypothesis paper, we propose that hoarding disorder may be an ancestral mammalian behavior, possibly hard-wired but dormant in present-day humans, that can be activated by traumatic experiences. To support this claim, we describe hoarding in ancestral mammals and provide examples of recurrence of traits, or atavisms, in humans and other mammals, highlighting its implications for neuropsychiatric diseases. We highlight the potential of using shrews as animal models for hoarding behavior and, considering the current knowledge on the molecular underpinnings of the disorder, we also point to limitations of the proposed connection.

### Introduction

Hoarding disorder (or compulsive hoarding) is characterized by persistent difficulty in discarding or parting with possessions, regardless of their monetary value. There is a strong perceived need to preserve the items and distress associated with discarding them. Hoarding individuals, thus, accumulate large numbers of possessions that congest and clutter active living areas to a point that compromise their intended uses. In the most prevalent acquisitive variant, the individual excessively collects, buys or steals items that are not needed or for which there is no available space. In addition to that, there are hoarding individuals that collect unhealthy amounts of animals (normally cats and dogs, but also other domestic and farm animals) [1]. Only recently this condition received its status as a separate mental disorder, in the Diagnostic and Statistical Manual of Mental Disorders, 5th edition (DSM-5) [1]. Previously, it was unclear whether compulsive hoarding was a separate disorder or if was part of obsessive-compulsive disorder [2,3]. DSM-5 classifies hoarding both as a separate disorder and as a possible symptom for obsessive-compulsive disorder. Prevalence is estimated as being around 5% in the general population, but it seems to increase in an age-dependent manner, varying from 2% in late teenagers to 8% in the elderly population [4].

Hoarding disorder became popular among the general public due to aggressive media coverage and reality television shows [5], which document the struggle of afflicted subjects when faced with the possibility of letting go all of their accumulated material. Among such shows, we highlight “Hoarders” (2009-current, 10 seasons, produced by

Screaming Flea Productions); “Hoarding: Buried alive” (2010-current, 5 seasons, produced by Discovery Studios); and “Obsessive compulsive hoarder” (2011, TV documentary, produced by RDF Television). There is still no verdict if these shows do some good to hoarding individuals, since they do not depict the disorder in its full spectrum and force them to face extreme, traumatic situations, such as ultimatums, to fuel audience [5,6].

Animal models for compulsive hoarding are considered behavior analogues instead of homologues, since the latter require evidence for shared evolutionary origin, which is conspicuously lacking in this case [7]. Multiple animals show hoarding behavior, including insects, birds and mammals, with corvids, parids, rats and pack rats being proposed as possible animal models for compulsive hoarding [7,8]. Among mammals, members the order Eulipotyphla (formerly part of Insectivora, comprising hedgehogs, solenodons, moles, and shrews) are especially interesting regarding their hoarding behavior [9–13].

One of the most studied eulipotyphlans is the short-tailed shrew (*Blarina brevicauda*). These shrews have an elaborate winter survival adaptation profile, which includes nest building and caching of food items [14]. These items range from dry fruits and seeds to living prey (various invertebrates, mice, and voles) that are kept in a comatose state. The amount and type of cached items varies according to the challenging environment. In times of plenty supply and mild temperature, caching decreases. The opposite happens during winter, with intense accumulation of highly nutritious food items [15]. This behavior, considered elaborate, ensures survival of these mammals, providing safety during unfavorable circumstances [14]. This is of special interest,

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since shrews have high metabolic rate, requiring intense caloric intake [15].

### The hypothesis

The eulipotyphlans are considered prototypical ancestral mammals. Despite not being truly ancestral in mammalian phylogenetic reconstructions [16], they are thought to best resemble the first eutherians to roam the Earth, sharing habitats with dinosaurs [9]. In this context, human hoarding can be a relic of this ancestral past, reactivated under specific circumstances.

We propose that a brain signaling pathway/molecular complex related to this kind of behavior lies dormant in humans. This dormancy may be due to pseudogenization of ancestral genes that are no longer adaptive to humans, which can be reactivated via mutation in the hoarding individuals, or due to epigenetic alterations, in which most human lineages have this pathway turned off, but which can be turned on under specific environmental conditions. In the first case, a functional gene, associated with hoarding behavior, could have suffered loss-of-function mutations (or nucleotide insertions/deletions), becoming an inactive gene or pseudogene [17]. This pseudogene could be reinstated as active by secondary mutations in certain (hoarding) individuals. In the second case, hoarding-associated genes could be turned off constitutively due to inheritable epigenetic markings, and only be turned on by specific events happening to the hoarding individual [18]. Such genetic and/or epigenetic activation conditions involve the sense of safety and survival of the individual. Much like generalized anxiety disorder, that can be modeled as a derailed fight-or-flight response [19], hoarding can be an untamable urge to control environmental variables that confer safety to the individual (hence its similarities with obsessive compulsive disorder). Past traumatic life events have been proposed and, to some extent, confirmed as risk factors for compulsive hoarding [20,21].

### Hypothesis evaluation

Humans behaving like shrews can be considered a form of atavism. Atavisms are recurrences of traits or characters in an organism that are typical of an ancestral form of the said organism. Examples of atavisms include whales and snakes with hind limbs, birds with teeth, flightless stick insects with wings, and horses with multiple digits [22]. In humans, they include congenital generalized hypertrichosis, true tails, zygodactyly, and tricavitary hearts [22–24]. Adult neurogenesis has been proposed by some as being a form of atavism (as discussed in [25]). Not only complex anatomical structures, but also complex behaviors have been observed as resurgences. These include narcolepsy, transition from bipedalism to quadrupedalism, reversal to free-living from parasitism, and redevelopment of sexual reproduction in parthenogenic organisms [26].

The evolutionary impact of atavisms has been extensively discussed, often depicting their negative effects for the individuals [22]. It is important to stress here that, even if atavisms are majorly deleterious in most species, variations that would lead to organism-level extinction are nurtured and cared for in most human societies (e.g. color-blindness, albinism). In addition to that, the human propensity to collect or hoard could have been extremely beneficial in evolutionary terms, considering primeval times of crisis and need, as could be said for other animal species in moments of scarcity of resources [21,27].

Imaging brain studies of hoarding individuals in comparison with non-hoarding individuals [28] and with hoarding traits arising after brain traumatic lesions [29] suggest a biological source for this behavior in humans [30]. The first step to test this hypothesis would be to perform the same experiments previously done on analogous animal models [7] on shrews that cache food, searching for similarities in their brain structures and function. Imaging studies of shrew brain activity would also be employed in comparison to human results.

Despite current advances in this field [13], shrews are considered difficult to maintain in captivity and hard to capture in the wild [9]. Comparative molecular characterization would be possible to some extent, since a low-coverage assembly of the European shrew (*Sorex araneus*) genome is already available at Ensembl [31], sequenced as part of the Mammalian Genome Project (NIH). In humans, there is some evidence for a genetic etiology for hoarding [30]. This includes the co-occurrence of hoarding with the established genetic velocardiofacial and Prader-Willi syndromes [32,33], the clustering of hoarding behavior in families with obsessive-compulsive disorder and the linkage of such behavior to specific chromosomal regions in such families [34,35]. Multiple correlation studies have found putative hoarding genetic markers as well [7].

Even with the advances in locating physiological sources for hoarding, the precipitating factors to develop the disorder are still unidentified [30]. Besides genetics, vulnerability factors include cognitive variables, such as information processing deficits and unusual beliefs [3]. Taking previous observations on agoraphobia [34], it has been proposed that a threatening environment may elicit a sense of safety and security only when assured by possessions [20,21]. Hoarding individuals also have a differential response to traumatic events. Emotional attachment (hypersentimentality), concerns about memory, and control over possessions are cognitive factors specifically related to hoarding individuals [2]. Many authors established that objects symbolize safety for hoarding individuals, much as agoraphobic individuals take items as beacons of safety in a dangerous world [2,21,36]. Such hypersentimentality is likely associated with the additional sense of controlling the (threatening) environment. It has been proposed that, by protecting possessions, the individuals are protecting an extension of themselves and their very safety mechanisms [37]. The proper relation between traumatic life events and stress with hoarding behavior still requires further investigation, but it is proposed that such hoarding-specific cognitions may be the agents that exacerbate hoarding [21,38]. The observation that hoarding individuals do not experience a greater deal of poverty during childhood when compared to non-hoarding individuals [30,38] reinforces the perception of threat (and not the threat itself) as a major factor in this disorder. The “possessions equal safety” association also describes the shrew caching behavior [14,15].

The mechanisms underlying mental health balance are largely unknown at this time and hoarding disorder is no exception. Nonetheless, even if the atavism hypothesis is not confirmed, shrews may provide a new working model for this condition, something that is urgently needed due to limitations of the current ones [7]. Considering that major breakthroughs in current biomedical sciences, including the gut-brain connection and ancient DNA de-extinction, started out as then-untestable hypotheses [39,40], we believe that the atavism hypothesis for compulsive hoarding may point the way to novel discoveries in this area of knowledge.

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### Declaration of Competing Interest

The authors declare no conflict of interest regarding this work.

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