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The uncanniness of written text is explained by configural deviation and not by processing disfluency

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Abstract

Deviating from human norms in human-looking artificial entities can elicit uncanny sensations, described as the *uncanny valley*. This study investigates in three tasks whether configural deviation in written text also increases uncanniness. It further evaluates whether the uncanniness of text is better explained by perceptual disfluency and especially deviations from specialized categories, or conceptual disfluency caused by ambiguity. In the first task, lower sentence readability predicted uncanniness, but deviating sentences were more uncanny than typical sentences despite being just as readable. Furthermore, familiarity with a language increased the effect of configural deviation on uncanniness but not the effect of non-configural deviation (blur). In the second and third tasks, semantically ambiguous words and sentences were not uncannier than typical sentences, but deviating, non-ambiguous sentences were. Deviations from categories with specialized processing mechanisms thus better fit the observed results as an explanation of the uncanny valley than ambiguity-based explanations.

Keywords

categorization ambiguity, configural processing, deviation from specialized categories, processing fluency, word processing

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Introduction

Uncanny Valley and Uncanniness

Artificial humanlike entities deviating from human norms are perceived as eerie or cold (Diel et al., 2022; MacDorman & Ishiguro 2006; Mori, 2012). Despite decades of research, the cognitive

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processes underlying this phenomenon, the *uncanny valley*, are not well understood. Various theories on the uncanny valley presume the effect is specific to human beings or animals, some of which are reviewed here: *Dehumanization* theory proposes that the initial attribution of mind to a non-human anthropomorphic face in the early stages of processing and its removal in later stages elicits a negative experience (Wang et al., 2020; Wang et al., 2015). *Misattribution* theories predict that ascribing human qualities like animacy or mind to entities recognized as non-human (or inanimate) elicits uncanniness (Gray & Wegner, 2012; Stein & Ohler, 2017). *Threat to human identity* theories predict that non-human entities appearing human undermine the distinctiveness of human identity, leading to an uncanny threat (Ferrari, et al., 2016; Huang et al., 2021; MacDorman & Entezari, 2015; MacDorman et al., 2009b; Müller et al., 2021; Ramey, 2005).

However, it is not clear whether these humans-specific processing *cause* uncanniness or merely correlate with uncanniness caused by, for example, deviation from familiar categories. As the uncanny valley has been found in perceiving animals (e.g., Schwind et al., 2018) and built environments (Diel & Lewis, in review; Diel & MacDorman, 2021), uncanny valley may occur for non-human categories, which could not be easily explained by explanations focussing on human-specific processing. Observed associations between mind or animacy perception and an uncanny valley could be merely correlational, and instead have the same cause: Subtle deviations or anomalies in facial appearance could interfere with mind or animacy attribution, and in addition appear uncanny. As attribution of mind and other human qualities enhance face-related processing (Deska & Hugenberg, 2017), they may increase the ability to detect slight deviations of facial appearance present in android or computer-generated faces, eliciting deviation-driven uncanniness. Hence, human-specific processes like the attribution of mind or dehumanization, may not cause uncanniness but instead correlate with another process that does.

Uncanniness may be caused by the detection of deviations in specialized categories: categories that humans have developed specialized neurocognitive processing mechanisms for. Specialization for certain categories can increase the sensitivity to deviations from the typical probabilistic appearance. These deviations could be detected especially with specialized (e.g., configural) processing. A higher sensitivity to deviations or errors for specialized categories could then lead to slightly deviating stimuli appearing unappealing, eerie or strange (Diel & Lewis, 2022; Diel & MacDorman, 2021). One way to investigate the extent to which the perception of uncanniness is relevant to domains beyond human or animal likeness is to test the effect of deviation on uncanniness in non-human stimulus categories, moderated by familiarity or specialization. Written text meets this criterion.

Uncanniness and Processing (Dis)Fluency. Some researchers propose that the uncanniness of entities deviating from the human norm stems from the processing disfluency elicited by categorization difficulty (Yamada et al., 2013; Carr et al., 2017). Cognitive fluency theory predicts that prototypical stimuli are easily processed and thus appealing (Halberstadt & Winkielman, 2013; Oppenheimer, 2008; Winkielman et al., 2003). Ambiguous stimuli however lead to processing disfluency, which elicits negative affect (Halberstadt & Winkielman, 2014). Context mediates processing disfluency's effect: ambiguous faces are rated negatively only when the task is to categorize them on their dimension of ambiguity (e.g., androgynous faces were rated more negatively after subjects had categorized the face as either female or male; Halberstadt & Winkielman, 2014; Owen et al., 2016; Winkielman et al., 2015). Similarly, attending to the human-likeness dimension of androids increases androids' uncanniness (Carr et al., 2017), indicating that attending to the stimulus' ambiguity increases the effect of processing disfluency, which then enhances uncanniness.

However, low processing fluency does not always decrease the aesthetics evaluation of stimuli (Jakesch et al., 2013). Furthermore, the most categorically ambiguous stimuli on a human likeness axis are not necessarily the uncanniest (MacDorman & Chattopadhyay, 2016; Mathur et al., 2020).

Although the humanoid stimuli used in MacDorman and Chattopadhyay (2016) and Mathur et al. (2020) were categorized on whether they were human or not, they may have been ambiguous on other dimensions, eliciting ambiguity-driven uncanniness. However, as previous research indicates that ambiguity should only play a role when the relevant ambiguous dimension was previously attended to (Carr et al., 2017), other ambiguous dimensions should not play a role if participants were asked to categorize the stimuli on whether they are human or not. Nevertheless, further research points towards an association between categorization difficulty and eeriness (Ferrey et al., 2015; Kawabe et al., 2017). In sum, research findings are inconsistent, and the relation between ambiguity-based disfluency and uncanniness remains unclear.

Uncanniness and Deviation From Specialized Categories. Other researchers proposed that heightened sensitivity to deviations in specialized categories, especially faces (Diel & Lewis, 2022; MacDorman et al., 2009a; MacDorman & Chattopadhyay, 2016; Matsuda et al., 2012), amplifies the uncanniness of atypical stimuli. Diel and Lewis (2022) found that participants' sensitivity to uncanniness in deviating faces was increased when faces were familiar compared with novel, and upright compared with inverted, indicating an effect of deviation from familiar stimuli driven by perceptual experience with the stimulus type, driven by an increased ability to detect deviations in specialized categories.

As configural processing of faces is thought to be mediated by experience differentiating faces based on configural patterns (Diamond & Carey, 1986), a specialization on a stimulus category would sensitize the processing system to detect even slight deviations from the typical configuration (see also Gauthier & Nelson, 2001; Tanaka & Gauthier, 1997).

Uncanniness would then be elicited by the relative atypicality of a stimulus depending on its distance to the acceptable variation of exemplars within a category. Uncanniness would further increase with the degree of familiarity to the category's typical variation. It need not depend on processing disfluency caused by the stimulus' (categorical) ambiguity.

Thus, uncanniness arising from deviations in familiar or specialized categories would be expected in various categories and most easily found in domains of higher familiarity and configural processing. Written text is one such domain, which will be explored next.

Deviation From Specialized Categories and Perceptual Disfluency. While processing fluency has been previously linked with the uncanny valley as an ambiguity-driven explanation (Carr et al., 2017), processing fluency has also been associated with a statistical occurrence (hence, typicality) of a stimulus, potentially linked to a decreased processing cost (Ryali et al., 2020). Processing disfluency would then relate less to categorical ambiguity rather than with the statistical atypicality of a stimulus based on its deviation from the prototypical appearance, for example in faces (Dotsch et al., 2016). Furthermore, it has been recently proposed that stimulus judgement is affected by the specific type of (dis-)fluency (*fluency-specificity hypothesis;* Vogel et al., 2020; see also Vogel et al., 2018): For example, disfluency of written text on a conceptual or semantic level influences truth estimation more than aesthetic appeal did, while the opposite pattern was observed for written text disfluent on a perceptual level.

Thus, ambiguity-based conceptual disfluency elicited by a stimulus may not have the same effect as perceptual disfluency caused by the stimulus' deviation from the learnt typical appearance, with the latter more likely to influence aesthetic appeal of a stimulus. In relation to the uncanny valley, uncanniness could thus be caused by disfluency created through increased processing need for deviating stimuli, regardless of whether these stimuli are categorically ambiguous. Thus, perceptual, not ambiguity-driven, disfluency, may underlie uncanniness.

The effect of perceptual disfluency depends on the expectations towards typical appearance, which may be driven by experience (Wänke & Hansen, 2015). Given that people are more

aware of deviations or changes in more familiar or specialized stimuli (Diel & Lewis, 2022), potential deviations may be more readily processed disfluently in those categories. Thus, the same type of deviation may appear more aesthetically unappealing in more, compared with less, specialized categories due to increased processing disfluency. In other words, the degree of familiarity or specialization would increase the sensitivity to deviations by increasing disfluency, and this effect would be more relevant for perceptual rather than for conceptual disfluency, given the specificity hypothesis (Diel & Lewis, 2022; Vogel et al., 2020).

Word Processing

Written words in a familiar language are recognized holistically (Pelli et al., 2003). Word and face recognition have been compared in previous research (Martelli et al., 2005) and have been associated with analogous, contralaterally aligned regions: the right fusiform gyrus for faces and the left fusiform gyrus for words and letter strings (Dehaene & Cohen, 2011; Dien, 2009; Hillis et al., 2005).

Given the similarities in word and face processing, multiple studies have successfully investigated configural processing of written words (Barnhart & Goldinger, 2013; Björnström et al., 2014; Gauthier et al., 2006; Wong et al., 2010) and its disruption in dyslexia (Conway et al., 2017). Recently, Wong et al. (2019) found that participants are sensitive to even slight changes in a word's configuration (e.g., slightly misaligning Latin letters or parts of a Chinese character), but only when they were familiar with the language and when words were presented upright instead of inverted, as inversion disrupts configural processing of stimuli that are typically experienced upright. As observers are sensitive to subtle changes in configural patterns of words, they should also be sensitive to the uncanniness of configural word deviations if deviation from specialized categories were to cause uncanniness.

Positive effects of processing fluency on word and sentence judgement have been previously observed; for example, rhyming statements are perceived as more truthful (McGlone & Tofighbakhsh, 2000), and regular words are perceived as more familiar (Whittlesea & Williams, 1998). According to the processing disfluency hypothesis, disfluent words or sentences should elicit negative evaluation, specifically uncanniness.

Perceptual Word Disfluency. Low-level perceptual processing fluency of words can be decreased by impairing readability of sentences, for example, by using unclear fonts or decreasing contrast (Reber et al., 2004). Increased perceptual word fluency makes written information more trustworthy (Shah & Oppenheimer, 2007) and decreases the perceived distance between the reader and the stimulus (Alter & Oppenheimer, 2008), potentially by reducing heuristic processing (Alter et al., 2007). If perceptual disfluency alone decreases the aesthetic judgement, any manipulations of words or sentences decreasing their readability would then also decrease their positive evaluation.

Given an expertise-based configural processing of words, deviations from the typical configuration of words should increase perceptual disfluency, and more so for words written in familiar languages. This high-level perceptual disfluency would fit the prediction that uncanniness is caused by deviations in specialized categories.

Conceptual (Semantic) Word Disfluency. Conceptual (semantic) processing fluency may occur when the meaning of words or sentences is ambiguous (Laurence et al., 2018). Semantically ambiguous words increase processing needs when the task is to categorize a word based on its meaning, for example within a semantic decision task (Hino et al., 2002; Piercey & Joordens, 2000; see also Eddington & Tokowicz, 2015). However, semantically ambiguous words may increase processing fluency because having multiple meanings may make them more accessible (Klepousniotou &

Baum, 2007; Yap et al., 2011). Ambiguous sentences are read faster, but elicit slower processing when disambiguation is required (Logačev & Vasishth, 2016; Swets et al., 2008). As semantic categorization decreases the processing fluency of ambiguous words and sentences likely by activating competing meanings and thus a cognitive conflict, ambiguous words and sentences should be negatively evaluated immediately after a decision on their semantic meaning is required (Piercey & Joordens, 2000; Owen et al., 2016).

Research Question and Hypotheses

In the present work, the effect of deviation and ambiguity on the uncanniness of written text is investigated and whether cognitive (dis)fluency or deviation from familiarity can better predict text uncanniness. The study is divided into three parts.

In the first part, the effect of familiarity on the uncanniness of configural and non-configural deviation of sentences is investigated and compared with the effect of sentence disfluency on sentence uncanniness. Sentence disfluency is operationalized as the participants' accuracy and response time for transcribing a presented sentence (*readability*). If cognitive disfluency specifically elicits the uncanniness of distorted words, stimulus manipulations decreasing fluency (readability) should also increase uncanniness:

1. Sentence readability negatively predicts the uncanniness ratings of English sentences (*disfluency*).

However, according to the theory based on deviations from specialized categories, configural deviation should increase the uncanniness of written sentences, and the effect of configural deviation specifically should increase with language familiarity.

> 2. Configural deviation of written sentences increases uncanniness most for a familiar language (*English*), less for an unfamiliar language that also uses Latin script (*Icelandic*), and not at all for a completely unfamiliar language and script (*Babylonian Cuneiform*). The effect of non-configural deviation (blur) on uncanniness is not affected by language familiarity (*configural deviation I*).

In the second part, the effect of conceptual fluency (semantic ambiguity) and deviation on uncanniness is investigated. Semantic ambiguity is operationalized as the consistency of participant responses in a semantic decision task. According to the disfluency hypothesis, ambiguous words should be more uncanny after attention has been put on their semantic ambiguity:

> 3. Ambiguous words are more uncanny after a semantic decision task encompassing two of the words' meanings than after a semantic decision task with unambiguous answers (*conceptual disfluency I*).

, the familiarity from deviation hypothesis would not predict an effect of conceptual disfluency effect, and instead an effect of configural deviation:

> 4. Configural deviations of words are rated more uncanny than non-deviating words, whether they are ambiguous or non-ambiguous (*configural deviation II*).

Since words with ambiguous meanings may increase processing fluency due to their multiple representations rather than decreasing it (Klepousniotou & Baum, 2007), a third part of the study focussed on the effect of conceptual disfluency on uncanniness in ambiguous sentences

rather than in words by investigating whether sentences with inconsistent interpretations across participants in a sentence ambiguity task were perceived as more uncanny than non-ambiguous sentences:

5. Ambiguous sentences are rated more uncanny than non-ambiguous sentences (*conceptual disfluency II*).
6. Configural deviations of sentences are rated more uncanny than non-deviating, ambiguous or non-ambiguous sentences (*configural deviation III*).

Methods

Participants

According to a power analysis, 50 participants were needed to achieve a power of $1 - \beta = 0.8$. Because, to our knowledge, no study has previously investigated the effect of distortion on uncanniness, a small effect size of $d = 0.25$ was used for the power analysis (Cohen, 1988). All 50 participants were undergraduate students from the Cardiff University School of Psychology and were on average 20 years old ($SD_{age} = 1.62$) and about 96% were female.

Stimuli

In the first part, stimuli were typical or manipulated versions of short sentences in three languages (English, Icelandic, Babylonian cuneiform). The sentences were taken from various passages of the *Epic of Gilgamesh* of the Electronic Text Corpus of Sumerian Literature (ETCSL)[1]: transliterations were transcribed into old Babylonian cuneiform using CuneifyPlus[2], and translations of the same passages were used for the English sentences. Icelandic sentences were the same passages translated by a native Icelandic speaker. A total of 15 sentences were used. For the configural distortion condition, letter and cuneiform positions and angles were changed. For the perceptual disfluency condition, sentences were blurred, and their contrasts decreased. Sentences from Babylonian literature were taken because 1) Babylonian cuneiform is guaranteed to be unfamiliar to participants, and 2) English translations were easily available. Examples of unedited and edited sentences are shown in Figure 1, and all unedited sentences in Table A1.

For the second part, a total of 15 semantically ambiguous words were collected. Words were presented either with two other words associated with two valid meanings of the word (*ambiguity condition*), with two other words associated with only one valid meaning (*non-ambiguity condition*) or like in the non-ambiguity condition but with the word being configurally distorted identical to the distortion in the first part (deviation condition). Examples of the stimuli per condition are seen in Figure 2, and all unedited stimuli in Table A2.

For the third part, 15 sentences have been selected which were either ambiguous (*ambiguity condition*) and had non-ambiguous counterparts (*non-ambiguity condition*). Non-ambiguous

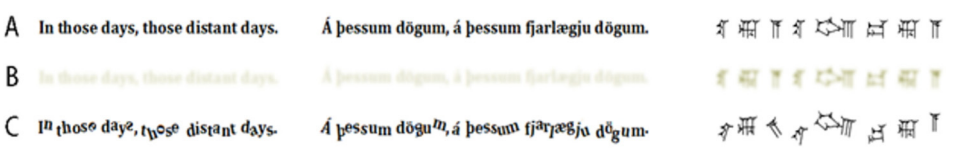

Figure 1. One example sentence in English (left), Icelandic (centre) and Babylonian (right). A = typical, B = blurred sentences. C = configurally distorted sentences.

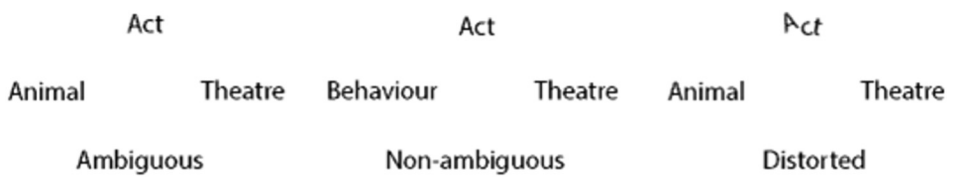

Figure 2. Example trials across conditions. The target word (top; here, 'Act') is presented either with two semantically associated context words (ambiguous condition), two context words of which only one is semantically related (non-ambiguous condition), or like the non-ambiguous but configurally distorted (distorted condition).

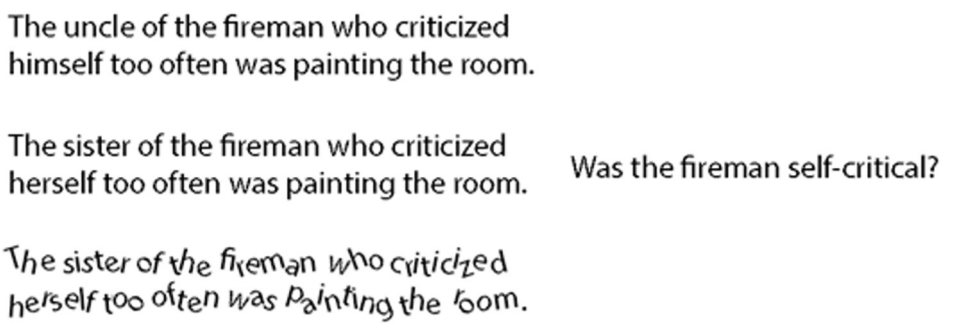

Figure 3. Example stimuli used in the final part of the study. On the left (up to down), an ambiguous sentence, a non-ambiguous sentence and a non-ambiguous-distorted sentence. On the right, the question asked on how participants interpreted the sentences.

counterparts which were configurally distorted identical to the previous two parts (*deviation condition*). Sentences were derived from the selection of most ambiguous sentences (close to 50% response preference in the ambiguous condition) and non-ambiguous variants in the study by Swets et al. (2008). Example sentences for each condition are seen in Figure 3, and all sentence stimuli across conditions are summarized in Table A3.

Design and Procedure

In summary, the study was divided into three independent study tasks: A readability and rating task (parts 1a and 1b), a semantic decision and rating task (part 2) and a sentence ambiguity and rating task (part 3). The readability task followed a 3×1 design varying text display (normal, blur, deviation), while the rating task in task 1 followed a 3×3 design with both text display and language (English, Icelandic, Babylonian) as variables. Tasks 2 and 3 were again 3×1 designs with varying text conditions (non-ambiguous, ambiguous, deviation). The tasks will now be further elaborated.

The study was conducted online. After giving informed consent, participants followed a link to the page where they performed the experiment. Participants were randomly assigned to one of three cross-condition groups. Cross-condition groups only differed in the conditions of the base word and sentence stimuli to avoid the repeated viewing effect from the same base stimuli appearing again in a different condition; thus, each text stimulus presented was unique. Each participant viewed five stimuli per condition. All participants took part in the parts described below.

Part 1a: Readability Task. In the readability task, participants saw English versions of the sentences which were either typical (*typical condition*), configurally distorted (*deviation condition*) or blurred and decreased in contrast (*perceptual disfluency condition*) in random order. Participants were asked to type the sentence into a text box as quickly as possible and viewed five sentences per condition which were not variants of the same sentences. Participants viewed sentences per condition, and never the same sentence in different conditions.

Part 1b: Rating Task. In the Rating task, participants viewed all sentences in the *typical*, *deviation*, and *perceptual disfluency conditions* in all languages in random order and rated them on four scales used in previous research: *uncanny*, *eerie*, *creepy* and *strange* (Diel et al., 2022). Each scale ranged from 1 to 100. Scales were presented sequentially, and simultaneously with the text stimulus. Participants had unlimited time for responding.

Part 2. Semantic Decision and Rating Task. In the Semantic Decision and Rating Task, participants first viewed an ambiguous target word accompanied by two context words to the left and right. Either both context words were semantically related to the target word (*ambiguity condition*), or only one word was semantically related (*non-ambiguity condition*), or only one word was semantically related but the target word was configurally distorted (*deviation condition*). Participants had four seconds to decide which of the context words were semantically related by pressing either the left or right key on their keyboard. Afterwards, participants had to rate the target word on a single *eerie/creepy/uncanny* scale ranging from 1 to 100. Again, participants had unlimited time to respond. Participants viewed five words per condition, and never the same word in different conditions.

Part 3: Sentence Ambiguity and Rating Task. In the Sentence Ambiguity and Rating Task, participants viewed a sentence that was ambiguous (*ambiguity condition*), non-ambiguous (*non-ambiguity condition*) or non-ambiguous but configurally distorted (*deviation condition*). Participants had unlimited time to decide whether the sentence presented was ambiguous or not, indicating their decision by pressing the left or right key. After responding, participants then rated the sentences identical to the Rating in the second part. Participants viewed five sentences per condition, and never the same sentence in different conditions.

Analysis and Ethics Statement

Analysis was conducted in R. Linear mixed models were used to control for participants, as well as linear regressions. Data cleaning was conducted by removing all outlier (1.5*IQR) uncanniness and categorization reaction time ratings for each stimulus. Numbers of outlier values removed were 20 out of 270 (task 1), 5 out of 810 (task 2), 41 out of 450 (task 3) and 31 out of 420 (task 4). The experiment was approved by the Cardiff University School of Psychology Ethics Committee in October 2021 (reference number: EC.21.09.14.6411G). The stimuli, data and analysis are available online at https://osf.io/yt9er.

Results

Part 1. Readability, Language and Uncanniness

Sentence Readability and Uncanniness. A linear mixed model was calculated with participant and base sentence as random factors and sentence type as fixed factors. Results show a significant main effect of both blur ($t(215) = 7.36$, $p < .001$) and deviation ($t(215) = 2.15$, $p = .033$) on

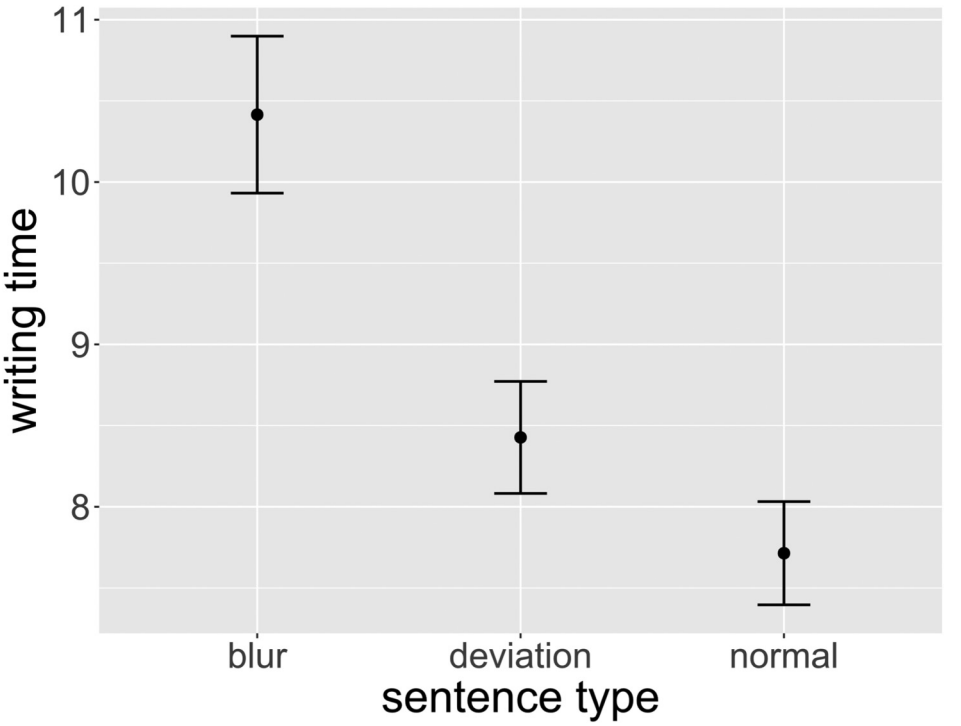

Figure 4. Average time needed to replicate the sentences (in seconds) divided by sentence type. Error bars represent by-participant standard errors.

readability. *P*-adjusted post hoc tests revealed that while blurred sentences were significantly more difficult to rewrite than typical ($t(216) = -7.36$, $p < .001$) and deviating sentences ($t(216) = 5.25$, $p < .001$), there was no difference in readability between typical and deviating sentences ($t(216) = -2.15$, $p = .082$). The data is depicted in Figure 4.

Another linear mixed model with the same random effects but readability as a fixed effect showed that reaction time significantly predicted uncanniness ($t(210) = 4.78$, $p < .001$, $R^2_{adj} = .41$). While the perceptual disfluency hypothesis is supported, it cannot explain why configurally deviating sentences are uncanny despite not being significantly more disfluent than typical sentences. Thus, perceptual disfluency cannot fully explain the results.

Sentence Language and Uncanniness Ratings. Sentence uncanniness ratings were tested using a linear mixed model with base sentence and participants as random effects and sentence type and language as mixed effects. Results show a main effect of language ($t(678) = -9.22$, $p < .001$), blur ($t(679) = 7.23$, $p < .001$) and deviation ($t(678) = 2.86$, $p = .004$) compared with typical. While the interaction between language and blur was not significant, the interaction between language and deviation was ($t(678) = 2.26$, $p = .024$).

P-adjusted Tukey tests furthermore showed that for Babylonian text, blur was more uncanny than deviation ($t(676) = 3.28$, $p_{adj} < .004$, $d = 0.53$) and typical ($t676) = 5.93$, $p_{adj} < .001$, $d = 0.95$), and deviation more uncanny than typical ($t(676) = 2.69$, $p_{adj} = .033$, $d = 0.43$). Similarly, for Icelandic, blur was more uncanny than deviation ($t(674) = 4.55$, $p_{adj} < .001$, $d = 0.72$) and typical ($t(675) = 8.65$, $p_{adj} < .001$, $d = 1.36$), and deviation more uncanny than typical ($t(675) = 4.07$, $p_{adj} < .001$, $d = 0.64$). For English, blur was not significantly more

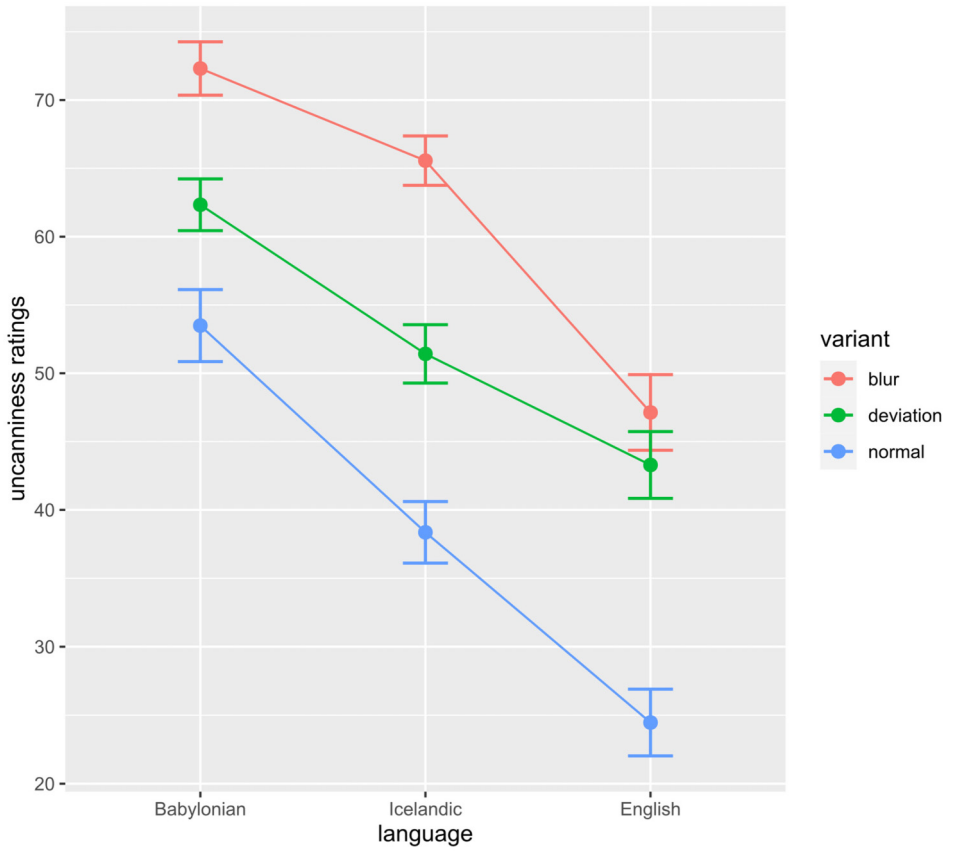

Figure 5. Average uncanniness ratings across sentence types and languages. Error bars represent standard errors.

uncanny than deviation ($t(674) = 1.34$, $p_{adj} = .818$, $d = 0.21$), while both blur ($t(675) = 7.22$, $p_{adj} < .001$, $d = 1.15$) and deviation ($t(674) = 5.84$, $p_{adj} < .001$, $d = 0.93$) were significantly more uncanny than typical. The data are summarized in Figure 5. Thus, the results support the deviation from familiarity hypothesis.

Part 2. Word Ambiguity and Uncanniness

Manipulation Check for Ambiguity. A manipulation check for ambiguity was done by comparing two indicators of categorization difficulty between word types: categorization reaction time and categorization response. Categorization responses were transformed into a categorization consistency scale, ranging from 0 (categorization at chance level) to 0.5 (consistent categorization across all participants). Linear mixed models with participants and base words as random effects and word type as fixed effects showed no effects of word ambiguity ($t(390) = 1.13$, $p_{adj} = .258$) or word distortion ($t(390) = 1.25$, $p_{adj} = .211$) on reaction time. However, word ambiguity ($t(28) = -2.32$, $p_{adj} = .028$), but not word deviation ($t(28) = -0.02$, $p_{adj} = .99$), had an effect on response consistency. Specifically, typical words were more consistent than ambiguous words ($t(28) = 2.32$, $p_{adj} = .028$), but not deviating words ($t(28) = 0.02$, $p_{adj} = .988$), and deviating words were more consistently categorized than

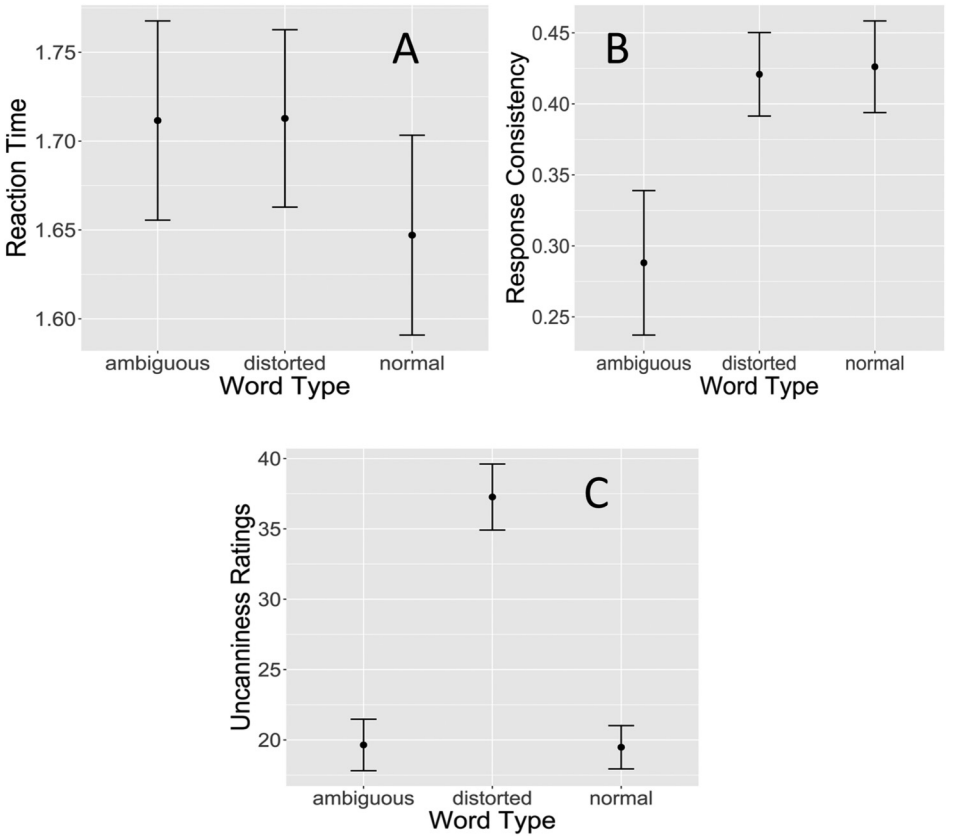

Figure 6. A: Average response reaction times across word types. B: Participants' average response consistency (0 = random, 0.5 = full consistency) across word types. C: Average uncanniness ratings across word types. Error bars represent standard errors.

ambiguous words ($t(28) = -2.3$, $p_{adj} = .015$). Reaction time and categorization data are summarized in Figures 6A and 6B. Thus, the ambiguity manipulation was successful.

Uncanniness Ratings. Linear mixed model analysis with participants and base word as random effects and word type as fixed effect showed no effect of both word ambiguity ($t(392) = 0.02$, $p = .98$), but an effect of deviation ($t(392) = 7.86$, $p < .001$) on uncanniness. Specifically, post hoc Tukey tests showed that while typical words were not less uncanny than ambiguous words ($t(392) = -0.02$, $p = .869$), both typical ($t(392) = -7.86$, $p < .001$) and ambiguous ($t(392) = -7.84$, $p < .001$) words were less uncanny than deviating words. Data is depicted in Figure 6C. Thus, the configural deviation hypothesis received stronger support than the conceptual disfluency hypothesis.

Part 3. Sentence Ambiguity and Uncanniness

Manipulation Check for Ambiguity. Reaction time and response consistency were used as indicators of a successful manipulation of ambiguity. Linear mixed models with participants and base sentences as random effects and sentence type as main effects showed a significant effect of sentence

ambiguity on reaction time ($t(379) = 3.65$, $p < .001$), but not of sentence distortion ($t(379) = -0.11$, $p = .91$). Specifically, post hoc Tukey tests show that ambiguous sentences needed a significantly longer reaction time than typical ($t(379) = 3.65$, $p < .001$) and deviating ($t(380) = 3.8$, $p < .001$) sentences, but there was no difference between deviating and typical sentences ($t(379) = 0.11$, $p = .91$). Furthermore, response consistency analysis showed an effect of ambiguity ($t(28) = 7.19$, $p < .001$), but not deviation ($t(28) = 0.42$, $p = .676$) on consistency, and post hoc Tukey tests show that ambiguous sentences had less response consistency than typical ($t(28) = 7.19$, $p < .001$) and deviating sentences ($t(28) = 6.77$, $p < .001$), which did not differ from one another ($t(28) = -0.42$, $p = .676$). Data is summarized in Figures 7A and 7B. The ambiguity manipulation was thus successful.

Uncanniness Ratings. A linear mixed model with participants and base sentence as random effects and sentence type as a fixed effect showed sentence deviation ($t(362) = 7.710$, $p < .001$) rather than sentence ambiguity ($t(362) = -0.14$, $p = .892$) had a significant effect on uncanniness. Post hoc Tukey tests showed that while typical sentences were not less uncanny than ambiguous sentences ($t(361) = 0.14$, $p = .911$), both typical ($t(361) = -7.71$) and ambiguous sentences

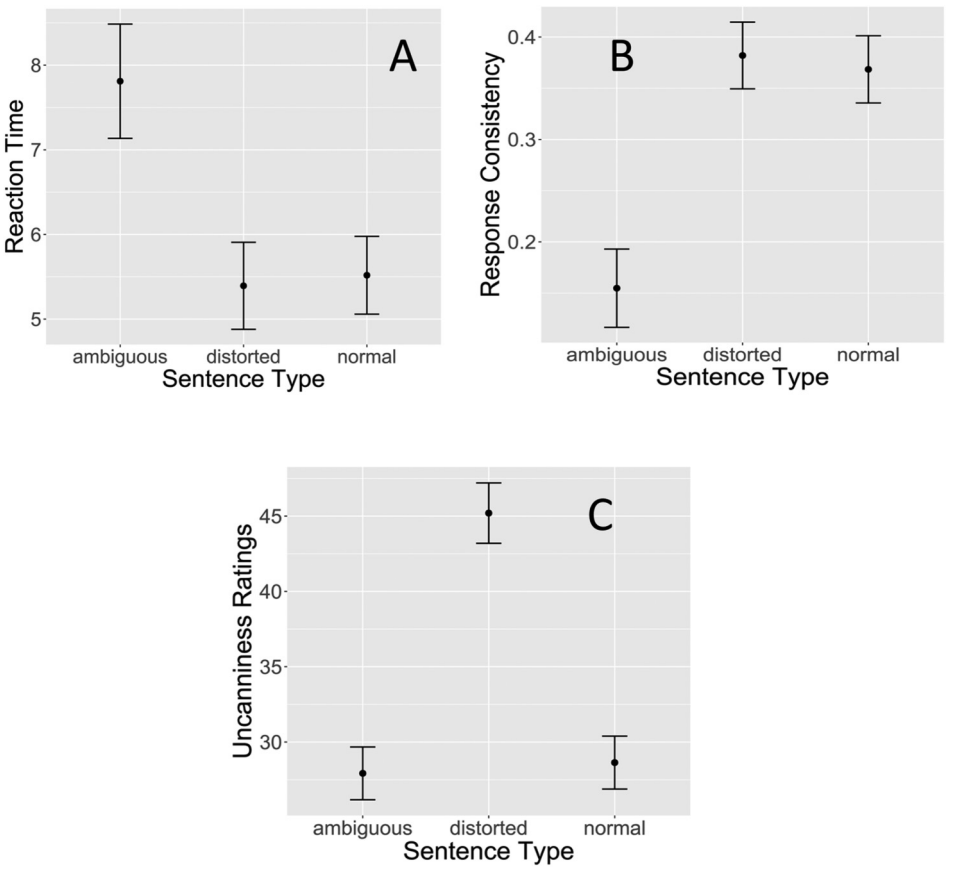

Figure 7. A: Average response reaction times across sentence types. B: Participants' response consistency (0 = random; 0.5 = full consistency) across sentence types. C: Average uncanniness ratings across sentence types. Error bars represent standard errors.

($t(362) = -7.87$, $p < .001$) were less uncanny than deviating sentences. The data is summarized in Figure 7C. Again, the configural distortion hypothesis received support rather than the conceptual disfluency hypothesis.

Discussion

Sentence Readability and Uncanniness

The first hypothesis (*disfluency*) states that the processing fluency of sentences should increase their uncanniness. Sentence readability reaction time was used to assess participants' ability to replicate a sentence in different conditions and used as an indicator of processing fluency because impaired sentence readability increases disfluency (Reber et al., 2004). Reaction time significantly predicted uncanniness ratings. Furthermore, sentence deviation did not significantly increase reaction time, while blurred sentences were significantly harder to replicate than both typical and deviating sentences. Thus, processing disfluency seemed highest for blurred sentences while it did not show any effect for deviating sentences. However, despite having the same readability as typical sentences, deviating English sentences were significantly more uncanny than typical sentence and comparably to blurred sentences. Thus, while time needed to replicate sentences could predict uncanniness ratings, the uncanniness of deviating sentences cannot be explained by processing disfluency. Thus, the first hypothesis (*disfluency*) is partially supported.

Sentence Familiarity and Uncanniness

The second hypothesis (*configural deviation I*) stated that the effect of deviation on uncanniness decreases as the language becomes less familiar. Specifically, deviating sentences should be most uncanny compared with typical sentences (most familiar) and least compared with Babylonian cuneiform (least familiar). Both blurred and deviating sentences were significantly more uncanny than typical sentences across languages. However, an interaction between language familiarity and deviation was observed for configurally deviating sentences, not for blurred sentences. In addition, effect sizes show that the uncanniness difference between deviating and typical sentences increased with language familiarity from Babylonian ($d = 0.43$) to Icelandic ($d = 0.65$) to English ($d = 0.93$), which was not observed for the difference between blurred and typical sentences (Babylonian: $d = 0.95$; Icelandic: $d = 1.36$; English: $d = 1.16$). Thus, the effect of configural deviation on uncanniness decreased with decreasing language familiarity, while the effect of non-configural deviation (blur) remained constant. Thus, the second hypothesis (*configural deviation I*) is supported.

Word and Sentence Ambiguity and Uncanniness

The third and fifth hypotheses (*conceptual disfluency I and II*) stated that ambiguity increases the uncanniness of words and sentences, respectively. In contrast, the fourth and sixth hypotheses stated that configural deviation of written words and sentences increases uncanniness. Ambiguity was manipulated by adding a lexical ambiguity condition for words and a semantic ambiguity condition for sentences. A manipulation check of ambiguity (differences in reaction time and response consistency) showed partial support of successful ambiguity manipulation for words, and full support for sentences. Nevertheless, both ambiguous words and sentences were not more uncanny than typical words and sentences. Instead, non-ambiguous but configurally deviating words and sentences were more uncanny than both typical and ambiguous variants. Thus, the results indicate that configural deviation, not ambiguity, elicits uncanniness (*configural deviation II and III*).

It is possible that the ambiguity manipulation in Tasks 2 and 3 could not compete with a manipulation as salient as the deviation condition, and hence was less uncanny as the deviation condition. Ambiguity was associated with aesthetic devaluation in previous research (e.g., Carr et al., 2017), but the effect may not be as strong as the effect of deviation on uncanniness. However, because the uncanniness difference between the normal and ambiguity condition was not significant, the results of this study do not indicate any kind of effect of ambiguity on uncanniness.

Processing disfluency is a reaction relative to the expectation of an occurrence (Wänke & Hansen, 2015). Hence, the typical variation of letter structure is expected to be much narrower than the variation of the content of a sentence. Hence, the observed effect of deviation, but not ambiguity, may be because the former condition elicits greater typicality-based fluency than the latter. Nevertheless, the results suggest that ambiguity-based disfluency alone is not sufficient to explain uncanniness.

Human-Specificity of Uncanniness

Various theories predict that uncanniness results from anomalies in human-specific processing (Stein & Ohler, 2017; Wang et al., 2020). However, the face stimuli used in studies investigating human-specific processes have been variants deviating from typical facial appearance. The present work shows that anomalies deviations in specialized categories like written text can elicit uncanniness in themselves, and human-specific processes can be excluded. Given the analogous processing of written text and faces, configural atypicalities in artificial faces may thus already be uncanny because of their deviation, while also influencing later human-specific processing like dehumanization or threatening human identity. Thus, uncanniness may be better understood as a reaction to deviations from highly familiar or specialized categories rather than being a response to stimuli deviating specifically on the perception of humanness.

Processing Fluency and Uncanniness

Previous researchers have suggested that the uncanniness of humanlike entities is elicited by processing disfluency caused by the entity's categorical ambiguity (e.g., Yamada et al., 2013). Ambiguity has been shown to lead to negative evaluation in faces (Halberstadt & Winkielman, 2014). However, the present results cannot support the notion that ambiguity, or conceptual disfluency, elicits uncanniness.

The role of categorical ambiguity in the uncanny valley has been a topic of debate. Some researchers failed to show that the most ambiguous stimuli were the most uncanny (Mathur et al., 2020). Similarly, certain stimulus categories that do not straddle categorical boundaries, like faces of people with disabilities, are still rated as uncanny (Diel & MacDorman, 2021). The uncanniness of some ambiguous stimuli may also be due to those stimuli deviating from the typical configuration, which is more likely when the stimuli are straddling categorical boundaries and thus are distant from the typical. Stimuli in between two categories may be compared with both categories' typical members, leading to an increased detection of deviations. The results are in accordance with previous research showing that processing disfluency affects liking more if it elicited on a perceptual, rather than a conceptual or semantic, level (Vogel et al., 2020). As with previous research, this effect is more pronounced for configural information in more familiar categories (Diel & Lewis, 2022). In sum, this study provides further evidence against the effect of ambiguity on uncanniness in favour of perceptual disfluency, especially disfluency caused by deviation from specialized categories.

Deviation From Familiarity and Uncanniness

Across tasks, configural deviation of words and sentences increased uncanniness. Furthermore, the effect of deviation on uncanniness increased with language familiarity. As sufficient experience with a written language allows holistic processing of words (Björnström et al., 2014; Wong et al., 2010) and sensitivity to configural distortions (Wong et al., 2019), the moderating effect of familiarity on uncanniness can be explained by an intrinsic negative evaluation of stimuli that deviate from learned configural patterns. Familiarity has been shown to moderate the effect of configural deviation on uncanniness in faces (Diel & Lewis, 2022) and novel stimuli (Diel & Lewis, in review). Here, the effect is replicated with text stimuli. The results nicely fit previous suggestions that the detection of errors through the processing of high-expertise categories underlies the uncanny valley effect of near humanlike entities, especially faces (Diel & MacDorman, 2021; MacDorman & Chattopadhyay, 2016; MacDorman et al., 2009; Matsuda et al., 2012). Previously, researchers suggested an evolutionary bias to avoid oddities and anomalies in conspecifics, especially in the face (MacDorman & Ishiguro, 2006), which would not be able to explain the uncanniness of deviating written text stimuli. However, as the processing of written text may use brain areas that would otherwise be used for processing of other specialized categories (Dehaene-Lambertz et al., 2018), the negative evaluation of configurally deviating faces may also spill over to written text processing or be a general reaction towards deviants of specialized categories. If this were true, activation of stimulus-specific processing areas would be necessary for the aesthetic devaluation of deviating stimuli. In addition, uncanniness can be predicted by configural deviation of a variety of specialized categories, including voices, places and categories of trained expertise (Gauthier et al., 2006; Tanaka & Gauthier, 1997).

However, it is unclear whether deviations in general lead to aesthetic devaluation (e.g., uncanniness), or whether the subjective reaction is relative to the category's valence. Vogel et al. (2021) found that deviations from categories eliciting negative valence are experienced more positive than typical category members. Hence, deviation could actually improve aesthetic appeal of stimuli if applied to negatively perceived categories. In this sense, negative evaluation of stimuli typically associated with the uncanny valley effect may be due to the deviation from otherwise positive categories (human beings, animals, or familiar words), rather than due to deviation in itself.

Conclusion

Previous research has shown that stimuli deviating from familiar patterns are evaluated negatively. While multiple theories on uncanniness presume human-specific processes, it is unclear whether the effect is specific to the perception of human or animal domains. Other authors suggest that uncanniness is a response to ambiguous stimuli which may occur for any stimulus category. This study is the first to investigate the effect of configural deviation of written text on uncanniness as an example of a highly specialized yet non-human stimulus domain. Deviating words and sentences appear more uncanny than typical or ambiguous variants, which do not differ from one another in uncanniness. Furthermore, the effect of configural deviation of text on uncanniness increased with language familiarity. Thus, uncanniness is an experience beyond human and animal domains, elicited by the detection of configural deviation in highly familiar categories. As the first study finding an effect of deviation on the uncanniness in written text stimuli, it provides evidence that uncanniness cannot be explained by predominant human- or animal-specific explanations of uncanniness like disease avoidance, or by category-related explanations like ambiguity. Instead, uncanniness seems to be a response to the detection of anomalies or deviations in highly specialized categories.

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Notes

1. https://etcsl.orinst.ox.ac.uk/#
2. http://cuneifyplus.arch.cam.ac.uk

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Appendix

Table A1. Unedited English and Icelandic sentences used in the first part of the study.

English	Icelandic
In those days, those distant days.	Á þessum dögum, á þessum fjarlægju dögum.
He lives outside the city.	Hann býr fyrir utan borgina.
There was a single tree.	Það var eitt tré.
His intuition led him to the forest.	Innsæið leiddi hann inn í skóginn.
He eats bread.	Hann borðar brauð.
They hugged and kissed.	Þau knúsuðust og kisstust.
They hit him and struck him.	Þeir slógu og börðu hann.
The king left the city.	Kóngurinn er farinn úr borginni.
He sat down in the dust.	Hann settist niður í rykið.

Table A2. Target word stimuli and the context words used in the second part of the study.

	Context words	
Target word	Ambiguous condition	Non-ambiguous condition
Act	Behaviour, Theatre	Animal, Theatre
Cause	Reason, Goal	Food, Goal
Block	Material, Mental	Clothing, Mental
Key	Lock, Typewriter	Lock, Alcohol
Board	Surfing, Ironing	Surfing, Grammar
Company	Social, Liquid	Social, Liquid
Case	Police, Grammar	Animal, Police
Beam	Laser, Construction	Clothing, Construction
Class	School, Social	Food, School
Space	Public, Cosmic	Public, Weapon
Magazine	Gun, Paper	Paper, Building
Oil	Fuel, Cooking	Singing, Cooking
Article	Paper, Grammar	Electrical, Grammar
Vision	Physical, Political	Cooking, Sense
Film	Coating, Movie	Food, Movie

Table A3. List of ambiguous and non-ambiguous sentences and questions used in the final part of the study.

Sentence	Question
The uncle/aunt of the fireman who criticized himself/herself too often was painting the room.	Was the fireman self-critical?
The mother/father of the bride who embarrassed himself/herself at the reception was complaining to the priest.	Was the bride embarrassed?
The partner/secretary of the salesman who amused himself/herself quite a bit was writing a letter to the editor.	Was the salesman amused?
The brother/hostess of the king who praised himself/herself constantly was bothered by the reporter.	Did the mayor like praise?
The niece/nephew of the waitress who hurt herself/himself on the bicycle was angry about the incident.	Did the waitress get hurt?
The father/mother of the deliveryman who made a fool of himself/herself at the party was greatly embarrassed.	Did the surgeon act like a fool?
The son/wife of the repairman who educated himself/herself at night loved going to the theatre.	Did the repairman get educated at night?
The assistant/daughter of the clergyman who drew attention to himself/herself all the time hated small children.	Was it the clergyman who drew attention?
The grandmother/grandfather of the stewardess who treated herself/himself an ice-cream was waiting at home.	Did the stewardess have an ince-cream?
The grand-nephew/grand-niece of the seaman who wrote himself/herself a note admired sailors very much.	Did the seaman write a note?
The sister/nephew of the baroness who admired herself/himself constantly enjoyed the attention.	Did the baroness admire herself?
The maid/bodyguard of the baroness who prepared herself/himself thoroughly came from the south.	Was the baroness prepared?
The uncle/aunt of the milkman who had to support himself/herself in the office received a phone call.	Did the milkman have a low income?
The landlady/landlord of the businessman who had locked himself in the office received a call.	Was the businessman locked up?
The daughter/son of the saleswoman who talked to herself/himself all the time walked into the room.	Was the saleswoman talking all the time?