Infants prefer the faces of strangers or mothers to morphed faces: an uncanny valley between social novelty and familiarity

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Summary

The "uncanny valley" response is a phenomenon involving the elicitation of a negative feeling and subsequent avoidant behaviour in human adults and infants as a result of viewing very realistic humanlike robots or computer avatars. It is hypothesised that this uncanny feeling occurs because the realistic synthetic characters elicit the concept of "human" but fail to satisfy it. Such violations of our normal expectations regarding social signals generate a feeling of unease. This conflict-induced uncanny valley between mutually exclusive categories (human and synthetic agent) raises a new question: could an uncanny feeling be elicited by other mutually exclusive categories, such as familiarity and novelty? Given that infants prefer both familiarity and novelty in social objects, we address this question as well as the associated developmental profile. Using the morphing technique and a preferential-looking paradigm, we demonstrated uncanny valley responses of infants to faces of mothers (i.e., familiarity) and strangers (i.e., novelty). Furthermore, this effect strengthened with the infant's age. We excluded the possibility that infants detect and avoid traces of morphing. This conclusion follows from our finding that the infants equally preferred strangers' faces and the morphed

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faces of two strangers. These results indicate that an uncanny valley between familiarity

and novelty may accentuate the categorical perception of familiar and novel objects.

Keywords

- Face perception

- Uncanny valley

- Development

- Preferential looking

- Mother

- Stranger

Short title

Uncanny valley between mother and other

1. Introduction

Highly realistic human-looking robots or computer avatars elicit negative feelings in humans [1-3], the so-called "uncanny valley" response [1]. Because this perceptual effect is also observed in nonhuman primate species [4] and human infants at a late developmental stage [5], the response is likely to have both evolutionary and developmental origins. Furthermore, experience with the early and highly selective perception of the faces of conspecifics has been emphasised as an important factor [5]. Once infants learn the prototype, they presumably acquire sufficient perceptual expertise to detect the slight anomalies inherent in realistic but synthetic avatar faces and begin to exhibit the uncanny valley effect because such violations of normal expectations regarding social signals generate a feeling of unease.

This conflict-induced uncanny valley between mutually exclusive categories (human and synthetic agent) raises a new question: could an uncanny valley response be elicited between other categories, such as familiarity and novelty? Although familiarity contradicts novelty in terms of experience, infants prefer both familiarity and novelty in objects [6]. While infants prefer stimuli that they have not previously encountered, such

as novel objects or sounds, they also exhibit preferences for stimuli with which they have extensive prior experience, such as the mother's face and voice [6]. Scientific research has generally identified and investigated these phenomena separately. In the mere exposure effect [7], familiar things are preferred over novel ones. Other studies utilise effects such as dishabituation, in which novel visual objects and places are preferred (e.g., [8]). However, it is unclear whether infants prefer things that assimilate the properties of both familiarity and novelty, that is, objects on the border between the two categories.

We investigate whether an uncanny valley lies between familiarity and novelty for infants, as previously observed for the features of humans and synthetic agents. We further aim to define the developmental profile of this uncanny valley response. For infants, mothers and strangers represent socially familiar and novel objects, respectively. It is known that six-month-old infants prefer to look at both mothers and strangers if they appear successively [9] whereas neural responses of infants differently process the two faces [9, 10]. These findings support the hypothesis that infants prefer both familiarity and novelty in social objects with different

underlying mechanisms. In the study reported here, we examined whether infants prefer faces on the border between mothers and strangers, and we investigated possible changes in such preferences during development. We evaluated infants' preferential viewing of three pairs of faces: mother *vs.* stranger, mother *vs.* intermediate face, and stranger *vs.* intermediate face. Infants in the second half of their first year begin to distinguish their mothers from strangers by their internal facial features and configural information [11] rather than by their hairlines or facial contour, as observed in neonates [12]. Intermediate faces between mothers and strangers were created by a morphing technique with a physical accuracy of 50% mother and 50% stranger faces rather than by recruiting mother-like strangers based on the experimenters' subjective impressions [9].

2. Materials and Methods

Fifty-one infants (21 male, 30 female; ages 6.9 to 13.1 months) were assigned to three groups according to the infant's age: 7-8 months (n = 17, mean = 7.7 months), 9-10 months (n = 20, mean = 9.6 months) and 11-12 months (n = 14, mean = 11.7 months). Six additional infants were excluded from the analysis because they did not complete the experimental protocol.

The infants were held in the lap of a parent and tested in a soundproof room. The parent wore a mask that prevented them from seeing the visual stimuli. In each of six trials, a pair of faces was presented side-by-side on an eye-tracker screen (Tobii X60, Stockholm, Sweden) that recorded the infants' eye movements. Data have been deposited in the Dryad repository: http://dx.doi. org/10.5061/dryad.s7t47.

Coloured photographs of mothers and strangers were taken prior to the experiments. The photographs showed a smiling face, a face with the individual's hair pinned up and the individual's face without glasses. To create intermediate faces, the faces of a mother and a stranger were morphed together using computer software (Sqirlz Morph 2.1: Xiberpix, Solihul, UK, www.xiberpix.com) to produce a new face that

consisted of 50% of the mother's face and 50% of the stranger's face. We used dynamic

facial expressions as visual stimuli for infants because Mori (1970) predicted that

movement accentuates the uncanny valley effect [1] and because infants are more

responsive to moving faces than to static faces [13] (see the electronic supplementary

material). The infants saw three different pairs of stimuli: mother *vs.* stranger, mother *vs.*

intermediate face, and stranger *vs.* intermediate face. The presentation was repeated

twice with photographs of different strangers as the stimuli representing strangers and

intermediate faces. Each test trial was presented for ten seconds. Each trial was

preceded by a stimulus intended to attract the infant's visual attention. The order of the

six test trials as well as the side on which a given face appeared was random and

counterbalanced across participants. A mother's face was used as a stranger's face for

other participants to furnish a homogeneous set of stimuli in this study. After the

experiment, we confirmed with each mother that the strangers whose faces were

presented were not acquaintances of her infant.

3. Results

Figure 1a depicts three different types of stimuli: mothers, intermediate faces and strangers (an example). The infants' viewing preferences are shown in figure 1b. The total time spent looking at each stimulus type was averaged across all test trials for each individual and then normalised to calculate proportions. The proportions were transformed with the arcsine function to achieve a normal distribution. A one-way repeated-measures ANOVA for all participants revealed a significant overall effect ($F_{2, 100} = 9.662$, $p < 0.001$, $\eta_p^2 = 0.162$) (figure 1b). Post hoc comparisons with a Bonferroni correction showed that the difference between mothers' faces and intermediate faces was significant, $p < .001$, and that the difference between strangers and intermediate faces was significant, $p < .001$. No significant difference was found between mothers and strangers, $p \sim 1.000$. These results showed that infants have a lower preference for intermediate faces. We next examined developmental changes in this preference. Although 7- to 8-month-old infants did not show a significant difference in their preferences among the stimuli ($F_{2, 32} = 1.207$, $p > 0.100$, $\eta_p^2 = 0.070$), infants at 9-10 months and at 11-12 months showed a significant difference ($F_{2, 38} = 5.179$, $p < 0.010$,

$\eta_p^2 = 0.214$; $F_{2, 26} = 4.342$, $p < 0.025$, $\eta_p^2 = 0.250$, respectively) (figure 1c). The interaction of Age × Stimulus type was not significant ($F(4, 96) = .908$, $p > .400$, $\eta_p^2 = .036$). This result represents a robust phenomenon occurring in the second half of the first year.

To exclude the possibility that infants detect traces of morphing and avoid intermediate faces, we presented stimuli representing pairs of strangers. One of these faces was that of a stranger, and the other was a morphed face of two different strangers (both stimuli were also dynamic faces) (figure 2a). The time spent looking at the two faces did not differ significantly ($t(19) = .205$, $p > .800$, $d = .092$) in 7- to 12-month-old infants (figure 2b).

4. Discussion

This study is the first to show that infants have a lower preference for intermediate faces between mothers and strangers than the original faces, and that this property is expressed in development. Given that infants prefer both mothers and strangers as socially familiar and novel objects, respectively [9] (also shown in figure 1b), our results indicate that infants' response to intermediate faces as neither familiar nor novel objects. If intermediate faces are recognised as mothers or strangers, infants should show equal increases in the time spent looking, as observed for the faces of mothers and strangers. Rather, infants may perceive intermediate faces in conjunction with an uncomfortable feeling, as shown by the uncanny valley response, the phenomenon whereby very realistic human-looking robots or computer avatars elicit negative feelings in human adults and infants [1, 2, 5] (also shown in nonhuman primates [4]). Infants may avoid these mother-like strangers because the intermediate face elicits the personal aspect of the mother but fails to satisfy it. Such a failure generates feelings of unease because the traits fall beyond the expected spectrum of everyday social experience with mothers.

Alternatively, it is possible that intermediate faces were perceived as lacking in novelty associated with strangers and lacking in any positive feelings with mothers, thereby causing infants to feel a *disinterest*. This explanation, however, seems less probable, as our preliminary observations with adult subjects indicated an uncanny rather than uninterested feeling in reaction to intermediate faces (see the electronic supplementary material). We have yet to reveal for infants whether the lower preference was associated with a feeling of unease or disinterest. Further physiological studies (e.g., skin conductance response or salivary cortisol level) will clarify whether the infant response represents an uncanny or uninterested valley.

Our findings raise interesting questions about the process underlying the emergence of the uncanny valley between social familiarity and novelty and its developmental changes. Two complementary processes are though to underlie the developmental changes: perceptual learning/differentiation of increasingly finer stimulus features [14, 15], and perceptual narrowing [16-18]. These two processes are likely to contribute to development of the perceptual expertise that is required for perception of subtle differences that define the mother's face. The increase observed in

the time spent looking at the mother's face relative to the time spent looking at

intermediate faces in infants between 7-8 months and 9-10 months of age suggests that

the infants' everyday experience with their mothers and the association of the mother's

face with generally positive consequences confer special status on the mother. With

experiences, infants gradually become expert at perceiving increasingly fine features of

the mother's face. This expertise may be further enhanced by perceptual narrowing,

which enables infants to address a more restricted range of stimulus attributes that can

now be explored in a more detailed manner.

In conclusion, the current research has demonstrated another type of the

uncanny valley between the face of the mother and the face of a stranger for infants, and

this phenomenon appears during development. The processes of perceptual

learning/differentiation and narrowing as well as the failure of normal expectations

linked to the mother's face may underlie the foundation for the emergence of the

uncanny valley between the face of the mother and the face of a stranger.

Acknowledgements

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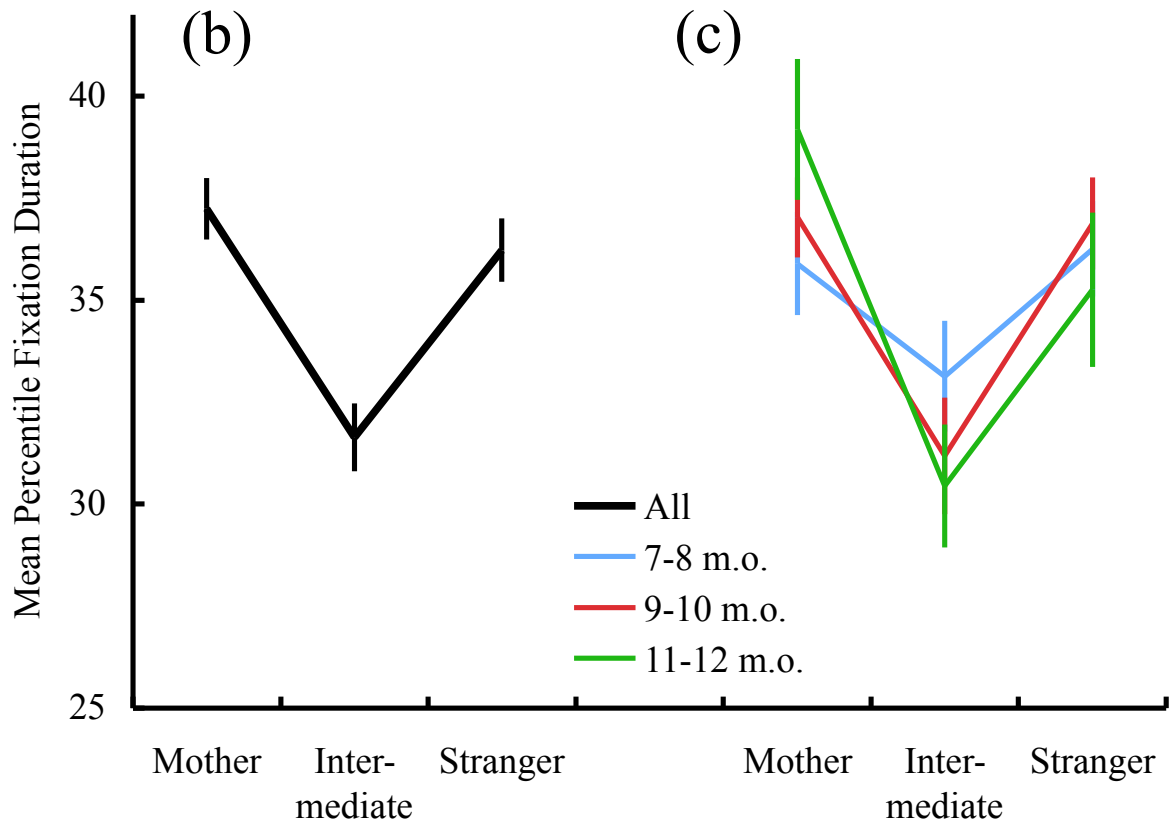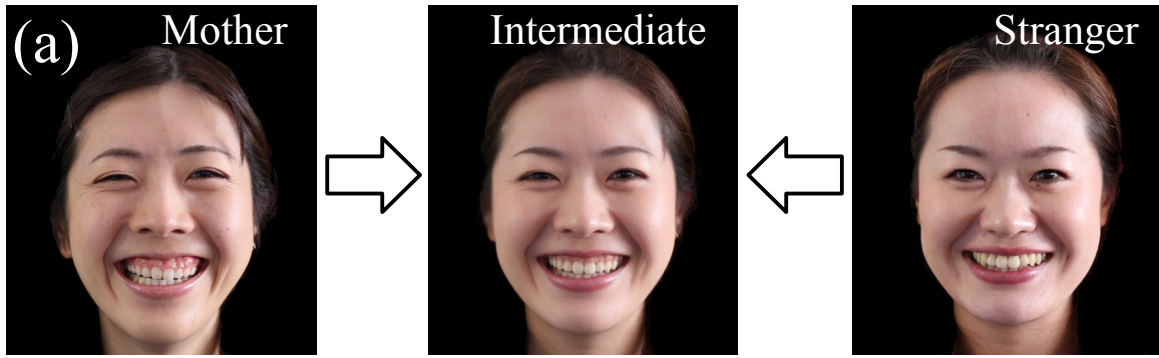
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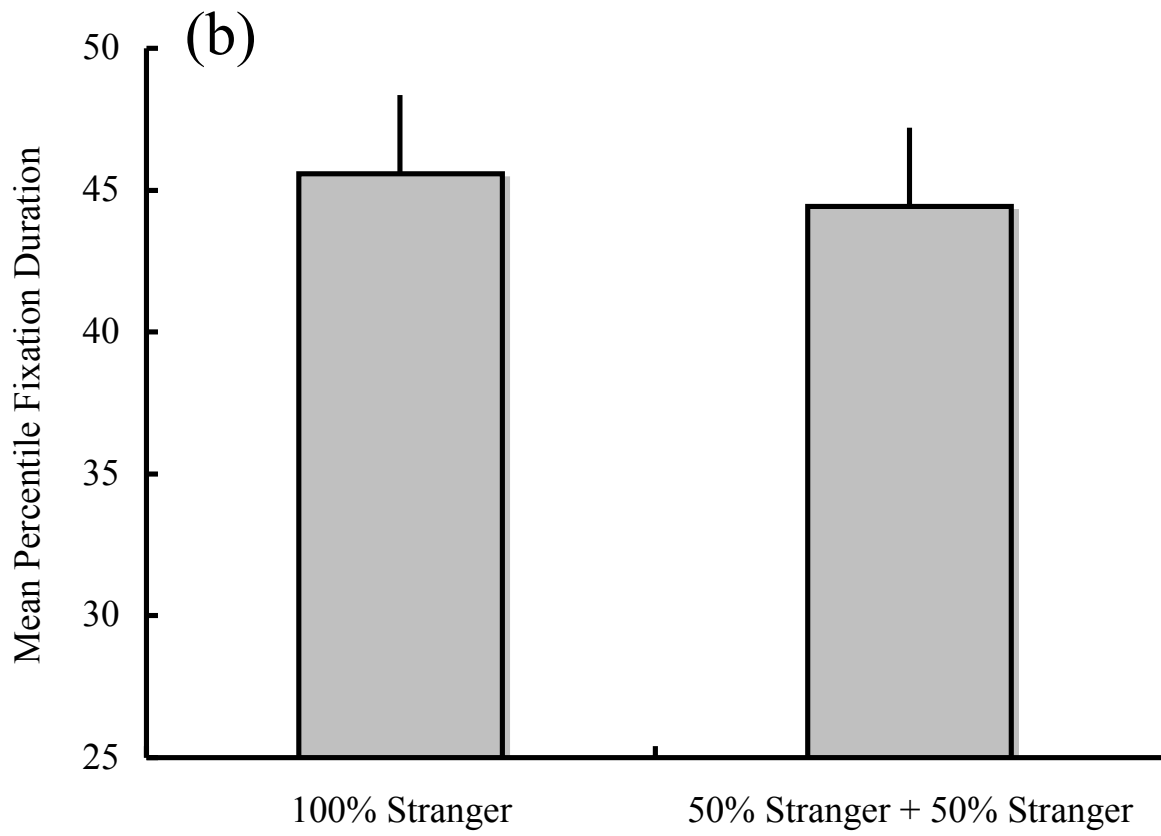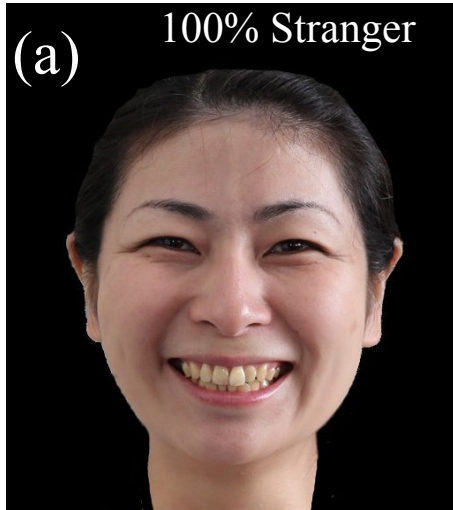
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Figure 1. Visual preferences of infants and the development of preferences for different face types. (a) An example of three different types of stimuli: mother's face (left), intermediate face (centre) and stranger's face (right). (b) The mean-percentile fixation duration on each of the face types across infants' ages. (c) Age-dependent differences of fixation durations. Error bars indicate standard errors of the mean. m.o.: month old.

Figure 2. Visual preferences of infants for different face types. (a) An example of two different types of stimuli: 100% stranger (left) and 50%-50% morphed face of different strangers (right). The figure (b) shows the mean-percentile fixation duration on each of the face-types: 100% stranger's face (left) and a 50%-50% morphed face of different strangers (right). Error bars indicate standard errors of the mean.

(a) Mother → Intermediate ← Stranger

(b)

(c)

Mean Percentile Fixation Duration

40

35

30

25

Mother   Inter-   Stranger
         mediate

Mother   Inter-   Stranger
         mediate

All
7-8 m.o.
9-10 m.o.
11-12 m.o.

(a) 100% Stranger; 50% Stranger + 50% Stranger

(b)

Electronic Supplementary Material (ESM)

Title:

Infants prefer the faces of strangers or mothers to morphed faces:
an uncanny valley between social novelty and familiarity?

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1. Supplementary Material and Methods

We created movie stimuli of smiling faces for mothers, strangers and intermediate faces, which are known as a *dynamic facial expression* or *dynamic face* of happiness [1-5]. Movie stimuli were created in the following way. First, two coloured photographs (neutral and smiling faces) were taken prior to the main experiments for each individual of mothers' and strangers' participants with hair pinned up and their glasses off. Next, between the neutral and smiling expressions for each participant, twenty-four intermediate images in 4% steps were created using computer-morphing techniques (Sqirlz Morph v2.1: Xiberpix, Solihul, UK, www.xiberpix.com). Then, to create a moving clip, a total of 26 images (one neutral image, 24 intermediate images, and the final smiling image) were presented in succession. Each image was presented for 40 ms, and the first and last images were additionally presented for 480 ms; thus each animation clip lasted for 2,000 ms. Each clip was repeated for five times (i.e., ten-second duration) in both the main and control experiments (figure 1 and 2 in the main text). This presentation speed has been found for adults to sufficiently reflect natural changes in the dynamic facial expressions of happiness [5].

2. Supplementary Results

We presented the mother's face twice for each participant, but different exemplars of the stranger and morphed face. There were possibilities that the repeated presentation of the mothers' faces might have induced a habituation of preference for the infants and shortened the looking time in the second presentation. To address this question, we compared infant looking times between the first and second presentations of their mother's faces. No significant difference was observed for the looking time ($t(50) = 1.270$, $p > 0.200$, $d = 0.196$).

3. Supplementary Discussion

(1) *Do mother's faces convey familiarity and/or rewarding connotation to infants?*

There is a possibility that the lower preference for faces intermediate between the infants' mothers and strangers was induced by rewarding the association. Indeed, several studies reported that an infant's preference for its mother's face varied with the style of mother-infant interaction [6] and the duration of parental leave for caregiving [7]. These results indicate that familiarity does not necessarily induce an infant's preference for their mother's face. Rather, a face with rewarding connotations might be preferable.

Hence, at least two different monotonic changes might be involved along a mother-stranger morphed continuum. One is a monotonic *fall* in a positive feeling associated with familiar faces. The other is a monotonic *rise* in novelty preferences. Overlaying the two monotonic preference changes with the mutually opposite slope would produce an uncanny (or disinterested) valley around the intermediate faces. Furthermore, the evidence that familiarity and novelty are distinct categories rather than both ends of a single axis was derived from neuroscience studies. Nakato et al. (2011) [8] dissociated familiarity (mother's faces) and novelty (stranger's faces) by revealing distinct representations in an infant's brain. Wilson and Rolls (1983) [9] showed that distinct amygdala neurons respond differently to familiar or novel objects. These results are consistent with our study, in which we showed that familiarity and novelty are distinct categories and that there is a categorical boundary (i.e., a valley) between them.

This uncanny (or disinterested) valley and its age dependency may suggest the presence and development of neuropsychological mechanisms in infants that accentuate the categorical differences between familiarity and novelty by eliciting the avoidance of (or disinterest in) ambiguity.

(2) *Is it an "uncanny" or "disinterested" valley between the face of the mother and the face of a stranger?*

We did not present direct evidence for negative emotions or feelings in infants associated with the intermediate faces. We should have evaluated physiological measures (e.g., skin conductance response or salivary cortisol level), but this was not the case.

Instead, we conducted a preliminary experiment with *adult* participants ($n = 10$) to assess subjective feelings in response to the intermediate faces between their parents and strangers. We created intermediate faces with the same method as in the main experiment. Subsequent to the presentation of the intermediate faces (10 seconds), we asked participants three questions. (1) Recognition: we asked them whether or not they recognized *familiar persons* (i.e., parents), whose faces were morphed to create the intermediate faces. All participants correctly recognized their parent's faces in the intermediate faces. (2) Forced choice #1: we asked participants to answer whether they felt a *positive* or *negative* emotion when they perceived the intermediate faces. Seven out of ten participants provided answers of a negative feeling. (3) Forced choice #2: we asked participants to answer whether or not an *uncanny/strange* feeling was induced when they perceived the intermediate faces. Eight out of ten participants provided answers of "yes". Importantly, when intermediate faces consisted of two strangers for participants, they reported neither a negative feeling nor an uncanny/strange feeling against these faces.

Although the results were obtained from our preliminary study of adult participants, these observations might provide an indirect yet supporting evidence for infant's negative/uncanny emotion against intermediate faces between mothers and strangers.

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