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*Research Article*

# NATURE CATCHES THE EYE - HUMAN GAZE BEHAVIOUR AS A DETECTOR OF SPONTANEOUS VISUAL ATTENTION

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## ABSTRACT

*Featuring wide and open spaces, scattered high trees and a sufficient amount of water, the African savanna constituted the environment in which early hominids developed bipedal locomotion and increased the size of both brain and social groups. Until today, the human species is thought to be adapted to the savanna habitat and to have evolved a strong preference for natural environments.*

*Based on the widely accepted savanna hypothesis and biophilia hypothesis, studies showed that in comparison to modern, man-made environments, natural ones are preferred. By using an electrooculogram, we investigated whether this preference already manifests in unconscious differential gaze behaviour in a laboratory study setting. 64 participants were confronted with 20 pairs of pictures, each consisting of a modern, man-made stimulus and of a natural stimulus. Stimuli were chosen so they matched in size, color and function of the depicted item. Stimuli were presented in random order for a duration of two seconds per pair. Other than previous studies, our participants weren't told to rank or rate those stimuli, but just to look at them. Our results show that the natural stimuli were looked at longer than the artificial ones. These results remain stable when controlled for sex, age and environmental preferences of our subjects. This indicates that the differential gaze behavior is triggered by involuntary and subconscious processes.*

**Keywords:** *Gaze behaviour, Evolution, EOG, Nature, Artificial, Visual Preference.*

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## INTRODUCTION

Featuring wide and open spaces, scattered high trees and a sufficient amount of water, the African savanna provided the setting where early hominids developed bipedal locomotion and increased the size of both brain and social groups. Anthropologists and evolutionary psychologists regard the savanna as the environment of evolutionary adaptedness of Homo sapiens (Orians & Herwagen, 1995). The savanna enabled our ancestors to quickly identify harmless and potentially harmful objects and situations, suitable food resources were easily accessible and an early detection of potential predators was possible due to the semi-open layout. Human preferences for nature may reflect the relevance of certain properties of the ancestral environment for the survival of our predecessors. Therefore, it is not surprising to see that even nowadays humans respond positively to natural landscapes, especially those that resemble the savanna habitat (Falk & Balling, 2010). Our perception of nature is seen as a persistent effect of the early days of human evolution. Until today, humans still prefer natural stimuli over man-made environments, irrespective of the surroundings they grew up in or currently live in. Also people born and raised in cities prefer natural over urban environments (Kaplan et al., 1972 and Ulrich, 1977).

The long-term survival of human ancestors in the savanna required the ability to process environmental information efficiently and quickly. Therefore, the development of adaptations for efficient processing of relevant visual stimuli was of utmost importance for collecting information about the environment. Until today, the response to visual exposure to nature goes far beyond a mere aesthetic appreciation. Humans respond to looking at natural scenes, like water and vegetation, with positive feelings as well as reduced sadness, fear and arousal (Wilson, 1984; Hartig & Staats, 2006; Ulrich, 1979, 1981; van den Berg et al., 2007). Urban settings hold the attention less long than natural stimuli. When experiencing a high level of arousal, anxiety and stress, people benefit most from visual exposure to nature (Ulrich, 1991). These effects can also be measured in physiological responses like heart rate and breathing rate (van den Berg et al, 2007).

This differential response to natural versus urban landscapes is independent from the complexity of the scene. While scenes with a higher degree of complexity were preferred over ones with lower complexity, natural stimuli were still preferred to urban ones, showing that preference is not a function of complexity and complexity cannot account for preference (Kaplan et al., 1972; Ulrich, 1981).

The profoundness of positive effects of natural stimuli on human physiology and physical and psychological well-being suggests a very basic mechanism. The present study investigates whether there is a perceptual bias towards natural stimuli that can account for these effects.

Perceptual biases are not necessarily linked to hedonic value. Neither previous studies nor the present one claim that natural stimuli are preferred because they are more positive. Quite the opposite: Biophilia and visual preference are rooted in evolutionary relevance. This relevance can be caused by stimuli being either, very good or very bad, i.e. stimuli associated with danger would trigger visual attention as well as stimuli associated with resources.

Visual preference can be measured in different ways. Previous studies have shown that the relative fixation time dedicated to a stimulus is linked to an increased probability to choose that stimulus. This means that the longer and more often a stimulus is looked at the more likely that stimulus will be picked in a choice task. Consequently, it is possible to predict the actual preference by analysing the gaze parameters (Galholt & Reingold, 2009; Jantathai et al., 2013; Sutterlin et al., 2008; Gidlöf et. al., 2017). This effect is more pronounced for stimuli causing highly positive and negative emotions than for emotionally neutral stimuli (Armel, Beaumel, & Rangel, 2008; Babcock, Pelz, & Fairchild, 2003; Holmes & Zanker, 2013; Krajbich, Armel, & Rangel, 2008; Maughan, Gutnikov, & Stevens, 2007; Rosler et al., 2005). The attention given to a certain stimulus can be influenced by a number of properties of the stimulus, like colour, contrast, presentation time and spatial layout as well as by individual characteristics of the subjects, such as personal knowledge, experience and preference (Lee et al., 2005; Shjomojo et al., 2003).

Gaze parameters are not only affected by the content and the complexity of the presented stimuli, but also colour is of relevance. Lee at al. (2005) demonstrated that fixation duration, number of fixations and number of revisits after looking at the other stimulus presented, correlate strongly with the colour preferences of the test person which are highly individual.

In this study we used electrooculography (EOG) for the measurement of gaze behaviour and visual preference. EOG is an eye tracking methodology that makes use of the changes in the corneoretinal potential generated by eye movements. The eye is a dipole with the cornea as the positive and the retina as the negative pole. The eye movements lead to changes of the vector of the electrical field which can be measured with electrodes. If placed on the left and the right side of the eye, horizontal eye movements can be assessed. In the current study, we measured horizontal movements only, as we presented our stimuli in a forced choice setup, and vertical movements were not investigated (ADINstruments, 2004; Trillenberg, 2012).

*Hypothesis*:
As shown in previous studies, humans tend to prefer natural stimuli over man-made ones. We hypothesised that subjects presented with pairs of natural and man-made content look longer at the natural stimulus than at the artificial one. By choosing a short presentation time of two seconds, we aimed to identify low-level, bottom-up visual preferences rather than top-down influenced preference shaped by memories and experience (Connor, 2004).

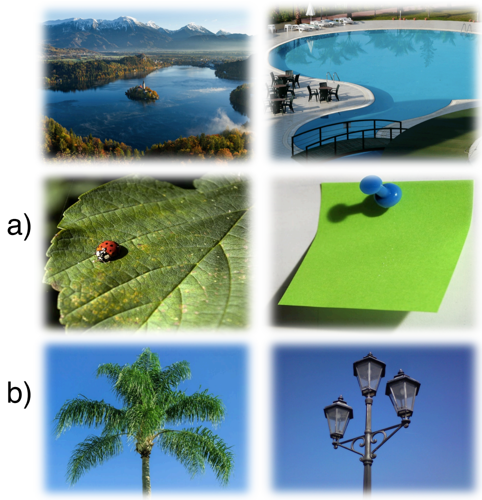


**Figure 1:** Examples of picture pairs of natural and artificial content. Similar in function (a), name (b) and shape (c).

# METHODS

## *Stimuli*

**Table 1:** Categorisation of used stimuli.

| Picture Pair | Classification |
|---|---|
| Lake - Pool | Function |
| Brain - Computer | Function |
| Pupil - Lense | Function |
| Fire Place - Lightbulb | Function |
| Horse - Motorbike | Function |
| Leaf - Sheet of paper | Name (German) |
| Mouse - Computer | Name (German) |
| Palm tree - Streetlight | Shape |
| Cell structure - Brick | Shape |
| Corals - Chimney | Shape |
| Eagle - Plane | Shape |
| Swan - Cruise ship | Shape |
| Mountain - Cathedral | Shape |
| Child - Robot | Shape |
| Snake - Cable | Shape |
| Leaves - Carpet | Shape |
| Jellyfish - Hat | Shape |
| Rock - Chair | Shape |
| Whale - Submarine | Shape |
| Galaxy - Drain | Shape |

To measure whether natural or artificial stimuli were looked at more, we chose pairs of pictures of landscapes, organisms and parts of organisms – one natural and one man-made one – that could be matched according to function, name or shape (Figure 1 and Table 1). Classification of pictures was done by 6 lab members, with an agreement of a Fleiss' Kappa value of .71.

Image pairs were chosen to match in colour, complexity and size.

Each subject looked at all pairs. Order and location of stimuli was assigned randomly. Half the subjects were presented with colour pictures, the other half saw the same pictures in grey scale.

In total 20 picture pairs were shown to each participant, which resulted in a total test duration of approximately 15 minutes, including briefing and debriefing. After the experiment subjects filled out a general questionnaire about the place they've grown up, time they spend in nature and/or with animals and the average usage of electronically devices.

## *Procedure*

Before the experiment, participants were asked for their informed consent and to provide demographic data. The electrodes of the electrooculogram were placed on both temples at eye level. The reference electrode was attached on the forehead. After that, the subjects were asked to take a seat in front of a computer screen and to place their chin on a chin rest, to avoid head movements during the experiment (Figure 2).

To calibrate the measurements, every subject was asked to look at a black cross in the middle of a blank screen before we started recording and in between each stimulus pair. The calibration cross and the stimulus pairs were all presented for a duration of two seconds. Electrodes captured eye movements based on the oscillation of the measured electronic potential by using the software ADInstruments PowerLab 26T (ADINstruments, 2004; Trillenberg, 2012).

Other than the request to focus on the black reference cross in between the presentation of the stimuli, the participants didn't get any further instructions or information.
A total of 64 participants were tested, of which 16 had to be excluded from further analysis due to technical problems like signal interferences caused by rapid head movements of the participants. The final data set, containing 33 female and 15 male subjects (age M=23.4, Std. Dev. 4.3), was analysed using IBM SPSS Statistics 23.

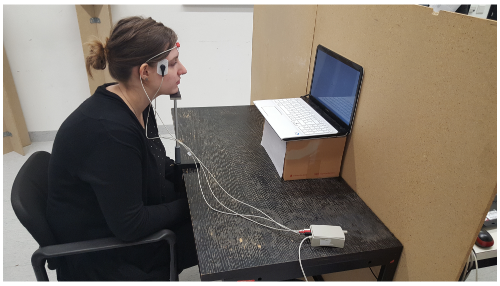

**Figure 2:** Experimental setup.

Participants were recruited at the Biology Building, Faculty of Life Sciences, University of Vienna. All subjects reported normal vision or were using appropriate visual aids.

## RESULTS

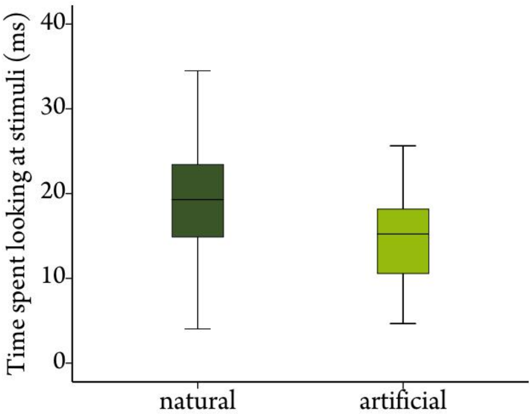


**Figure 3:** Participants paid more visual attention to the natural stimuli.

When comparing the overall time looked at pictures with natural versus artificial content with an U-test, the natural ones were looked at longer ($n=48$, $Z=-3.846$ $p<.01$). This finding remains stable when controlled for sex ($n=48$, $Z=-.990$, $p>.05$), age and environmental preference of the subjects ($n=48$, $r=-.225$, $p>.05$). There was no significant difference between the different groups of picture classification (function, name or shape) and the effect remained unchanged, whether the pictures were shown in colour or in black and white ($n=48$, $Z=-1.022$, $p>.05$).

When comparing the single picture pairs to each other, not everyone showed a significant difference in the time it was looked at (Tabel 2). But even when not showing a significant result, just in two picture pairs (Eagle - Plane and Fireplace - Lightbulb) the artificial stimulus was looked at longer.

**Table 2:** Gaze duration results in detail.

| Picture Pair | *p*-value | Mean rank | Mean rank |
|---|---|---|---|
| Lake - Pool | .108 | 48.88 | 40.13 |
| Brain - Computer | .001* | 58.09 | 38.91 |
| Pupil - Lense | .003* | 55.97 | 39.03 |
| Fire Place - Lightbulb | .361 | 46.88 | 52.12 |
| Horse - Motorbike | .000** | 62.82 | 34.18 |
| Leaf - Sheet of paper | .000** | 49.82 | 29.18 |
| Mouse - Computer | .008* | 48.44 | 34.56 |
| Palm tree - Streetlight | .745 | 48.41 | 46.59 |
| Cell structure - Brick | .137 | 42.26 | 34.74 |
| Corals - Chimney | .001* | 47.74 | 31.26 |
| Eagle - Plane | .679 | 47.32 | 49.68 |
| Swan - Cruise ship | .012* | 55.66 | 41.34 |
| Mountain - Cathedral | .803 | 48.20 | 46.80 |
| Child - Robot | .000** | 57.57 | 33.43 |
| Snake - Cable | .031* | 49.30 | 37.70 |
| Leaves - Carpet | .020* | 45.49 | 33.51 |
| Jellyfish - Hat | .065 | 45.30 | 35.70 |
| Rock - Chair | .519 | 41.15 | 37.85 |
| Whale - Submarine | .007* | 44.23 | 30.77 |
| Galaxy - Drain | .593 | 37.82 | 35.18 |

*$p$<.05, **$p$<.000

## DISCUSSION

Our findings are in line with previous studies that demonstrated a clear preference for natural content even in modern humans (Hartig & Staats, 2006; Ulrich, 1979, 1981; van den Berg et al., 2007). This human appreciation of nature likely has evolved over a long time. When people were asked to rate and rank different kinds of natural surroundings, Strumse (1996) found a sex difference in evolutionary aesthetics. As nature per se was of equal importance for our male and female ancestors, it is not surprising that our results, where people just looked at an either natural or artificial stimulus, show no sign of sex differences. Other than questionnaire studies, that produce very noisy data, physiological studies target more basic and less noisy signals. Therefore, the sample size required is usually much smaller for physiological studies than for questionnaires. Potentially intervening variables, such as whether the participants were born and raised in a rural or urban environment, or the amount of time spent in nature on a regular basis, do not affect the preference for natural stimuli. This basic quality of differential preference is an indicator of the importance of natural environments in our evolutionary history.

Lee et al. (2005) stated that colours trigger visual attention and that colour preference plays an important role in modifying gaze behaviour. To control for this bias, we showed pictures to our subjects either in colour or in black and white. There was no significant difference in gaze behaviour between these two sets of stimuli. Taking a closer look at the single combinations revealed that with the exception of two pairs, the natural stimulus is preferred over the artificial one. The Eagle - Plane pair shows almost no difference, and the Fireplace - Lightbulb pair might have been an unlucky choice in the first place, as fire is not necessarily a natural stimulus either, albeit having been part of human evolutionary history longer than electricity.

Using an electrooculogram is a non-invasive and relatively easy and cheap way to measure eye gaze behaviour, especially when focussed on rather clear measurements of gaze duration on large areas. Nonetheless, it is not without problems. The correct placement of the electrodes is essential for data quality. In this experiment, the electrodes were placed on both temples and on the forehead. These areas are comparably suitable, as strong hair-growth can prevent the electrodes from having proper skin contact. Uninterrupted skin contact is vital for a good signal. Previous studies have also shown that loose skin cells in the relevant areas can affect the signal (Venkataramanan et al., 2005). One major source of data inaccuracies is that even the smallest head movement, talking, sneezing and sometimes even blinking can affect the recorded signal and render the data useless. We attempted to minimise those artefacts by using a chin rest and a small and quiet operating room. Nonetheless, a quite large proportion of data points had to be discarded due to errors in the signal.

The people participating in this experiment were mainly biology students of the University of Vienna. This might have an effect on the results, as biology students usually spend a lot of time in nature due to their study program and practical field courses. This might have implications for the conscious preference for natural stimuli, it is, however, unlikely that the physiology of sensory perception is affected.

This study indicates that our preference for natural stimuli might be physiologically rooted in the way our visual apparatus works, rather than in high order cognitive processes, as differential gaze behaviour occurs despite very short presentation times. Follow-up studies should address the question, which properties of natural stimuli are responsible for this effect.

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