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Faculty of Mathematics, Physics and Informatics

Change Detection in Peripheral Vision Using Art Paintings and Snapshots

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Detekcia zmien v rámci periférneho videnia pomocou využitia umeleckých obrazov a fotografií

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Aim: To design and test the experiment to detect changes in the peripheral field of vision, which affects the cognitive processing of input. To find the size and shape of this field and then test the ability to notice a change in this field and outside of it. To compare the results of experiment on capability to detect changes while viewing the artistic paintings and the snapshots of real scenes.

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Cieľ: Navrhnutie a testovanie experimentu na detekciu zmien v periférnom poli videnia, ktoré má vplyv na kognitívne spracovanie vstupu. Zistenie veľkosti a tvaru tohto poľa a následné testovanie schopnosti všimnúť si zmenu v tomto poli a mimo neho.

Porovnanie výsledkov experimentu skúmajúceho schopnosť detekcie zmien počas pozerania sa na umelecký obraz a na fotografiu reálnej scény.

Vedúci: doc. PhDr. Ján Rybár, PhD.

I hereby declare that I have written this thesis on my own, under the guidance of my supervisors, and using the literature sources listed in the bibliography.

....

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Abstract

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Peripheral field of vision provides a better concept and understanding of the environment in which the person is located. It gives us the ability to grasp the whole scene at once without the necessity to look at everything separately. One of its purposes is to catch one's attention. We were interested in the question whether is the processing of visual perception inside the peripheral field of vision influenced by the top-down information processing of the brain. We approached this question by testing the detection of changes on art paintings and on the snapshots of real life. The hypothesis was that there would be a significant difference in detecting the changes between these two types of visual inputs. There are scientific proofs that art has certain impact on human psyche, but is this impact so strong that it could influence the visual processing of information in the brain? Are people better prepared to notice a change that will happen in the environment that is more natural to them, or are they going to be distracted by the art and will not be able to notice the change at all? There is of course also possibility that there will be no difference at all.

We have decided to split our research into two parts. During the first part, we created our own version of the previous experiments on the size and shape of peripheral field of vision that is involved in cognitive processes. We have found it to have elliptic shape of certain size that corresponded with settings and equipment in our laboratory.

The finding of the size and shape of this ellipse was important for the second part of our experiment, where we measured the detection of changes itself, on digitised paintings and on snapshots. We mapped the acquired ellipse to the image and determined whether the change occurred inside or outside of it. This information was compared with the results of successfully/unsuccessfully detected changes. As we were interested in top-down processing, we determined that successfully detected change was the one when the participant answered what exactly changed on image, not that just a change occurred.

We managed to find out that there really occurs certain different approach to paintings and snapshots. During the detection of changes on snapshots, the participants were acting rationally and if they did not notice the change, they acknowledged it straight away. On the contrary, when viewing the paintings, they often, probably unconsciously, started to fabricate the different versions of changes that could have happened.

Keywords: eye-tracking, peripheral vision, foveal vision, change blindness,
top-down processing

Abstrakt

PÄTOPRSTÁ, Eliška: *Detekcia zmien v rámci periférneho videnia pomocou využitia umeleckých obrazov a fotografií.* [Diplomová práca], Univerzita Komenského v Bratislave. Fakulta Matematiky, Fyziky a Informatiky; Katedra Aplikovanej Informatiky. Vedúci práce: Ján Rybár. Bratislava: UK, 2014, 67 str.

Pole periférneho videnia umožňuje lepšie pochopenie prostredie v ktorom sa osoba nachádza. Dáva nám schopnosť zachytiť celú scénu naraz bez nutnosti pozerať sa na všetko zvlášť. Jeho úlohou je taktiež zaregistrovať zmenu v okolí. Zaujímalo nás, či je spracovanie vizuálneho vnímania v periférnom poli videnia ovplyvnené spracovaním informácií mozgu zhora-nadol. Vyskúšali sme to testom na detekciu zmien na umeleckých maľbách a fotografiách reálneho života. Hypotéza bola, že nájdeme výrazný rozdiel v detekcií zmien v týchto dvoch typoch vizuálnych vstupov. Sú vedecké dôkazy o tom, že umenie má istý vplyv na psychiku človeka. Je však tak silný že by dokázal ovplyvniť vizuálne spracovanie informácií? Sú ľudia lepšie pripravení na spozorovanie zmien v prostredí ktoré im je prirodzenejšie, alebo budú rozptýlení umením a nebudú schopní tieto zmeny spozorovať vôbec? Bola tu samozrejme aj možnosť, že v žiadnom z týchto prípadov rozdiel nenastane.

Rozhodli sme sa náš výskum rozdeliť na dve časti. Počas prvej z nich sme vytvorili svoju vlastnú verziu predchádzajúcich experimentov skúmajúcich rozmery a tvar poľa periférneho videnia podieľajúceho sa na kognitívnych procesoch. Zistili sme, že má tvar elipsy istej veľkosti, ktorá korešpondovala s nastaveniami a vybavením v našom laboratóriu.

Zistenie veľkosti a tvaru tejto elipsy bolo dôležité pre druhú časť nášho experimentu, kde sme merali detekciu zmien ako takú, na digitalizovaných maľbách a fotografiách. Priložili sme získanú elipsu do stredu obrazu a určili sme, či sa zmena prejavila v jej vnútri alebo vonku. Tieto informácie sme porovnali s výsledkami úspešne alebo neúspešne zaregistrovaných zmien. Keďže nás zaujímalo spracovanie informácií zhora-nadol, stanovili sme, že úspešne spozorované zmeny boli tie, kde participant uviedol čo presne sa na obrázku

zmenilo a nie tie kde participant uviedol že zmenu spozoroval, ale nevie určiť čo sa zmenilo.

Podarilo sa nám zistiť, že naozaj dochádza k istému rozdielnemu prístupu k obrazom a fotografiám. Kým sa pri sledovaní zmien na fotografiách participanti správali racionálne a keď si zmenu nevšimli, tak to priamo priznali, na rozdiel od obrazov, kedy si často, pravdepodobne podvedome, vymýšľali rôzne verzie zmien ktoré mohli nastať.

Kľúčové slová: eye-tracking, periférne videnie, zrenicové videnie, slepota zmien, spracovanie informácií zhora-nadol

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1 THEORETICAL BACKGROUND

1.1 PERCEPTION PROCESSING

1.1.1 Visual perception theory

Salient items that are different from their neighbours tend to attract attention (Egeth, 1977; Julesz, 1986; Moraglia, 1989). The information that guides ones attention to that item can be labelled as bottom-up —meaning that it did not depend on the observer’s knowledge of the stimulus. The stimulus itself provides the guidance (Wolfe, Butcher, Lee & Hyle, 2003).

Psychologists distinguish between two types of processes in perception: bottom-up processing and top-down processing. Gregory (1970) who has proposed a constructivist (indirect) theory of perception which is a 'top-down' theory.

Bottom-up processing is also known as data-driven processing, because perception begins with the stimulus itself. Processing is carried out in one direction from the retina to the visual cortex, with each successive stage in the visual pathway carrying out ever more complex analysis of the input.

Top-down processing refers to the use of contextual information in pattern recognition. For example, understanding difficult handwriting is easier when reading complete sentences than when reading single and isolated words. This is because the meaning of the surrounding words provide a context to aid understanding (McLeod, 2007).

Top-down information can come in several forms. Position information can be used to guide attention. Instead of being told explicitly that the target is white and vertical, the observer might be told that the target is the item in the upper left corner. Implicit information can also be considered a form of top-down information. Maljkovic and Nakayama (1994, 1996) showed that attention was more swiftly deployed to a red item inefficient target items had also been red. (Wolfe, Butcher, Lee & Hyle, 2003)

A lot of information reaches the eye, but much is lost by the time it reaches the brain (Gregory estimates about 90% is lost). Therefore, the brain has to guess what a person sees based on past experiences. We actively construct our perception of reality. Our perceptions of the world are hypotheses based on past experiences and stored information. Sensory receptors receive information from the environment, which is then combined with previously stored information about the world which we have built up as a result of experience.

1.1.2 Peripheral vision

Vision is a dynamic process and is composed of both foveal and peripheral modes of seeing (Hilgard et al., 1975).

The fovea is a tiny region at the centre of vision with the highest visual resolution, which extends to the boundary of the rod-free area of the retina (~1°-eccentricity) (Polyak, 1941; Yamada, 1969). The parafovea extends to the foveal rim, where the highest density of rods is found (~4–5°-eccentricity) (Beard & Ahumada, 1999; Coletta & Williams, 1987; Rayner et. al., 1981). Vision scientists most commonly refer to all vision beyond the parafovea as peripheral vision (e.g., Hollingworth, Schrock, & Henderson, 2001; Holmes, Cohen, Haith, & Morrison, 1977; Rayner et al., 1981; Shimozaki, Chen, Abbey, & Eckstein, 2007; van Diepen & Wampers, 1998), which we will do as well.

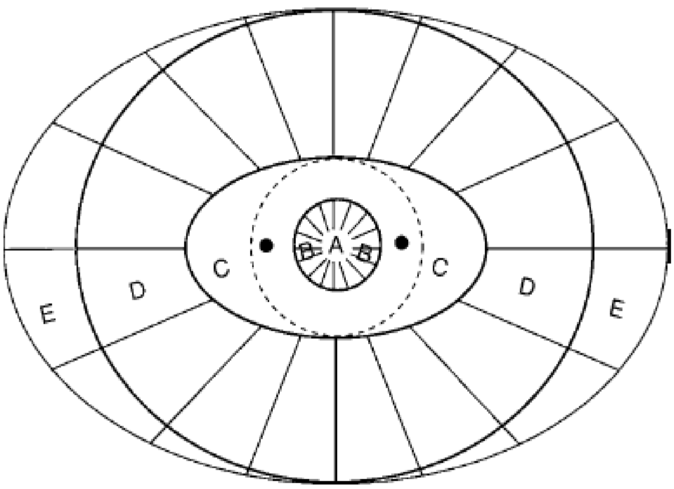


Figure 1. Schematic representation of the visual field. (A) the fovea which shows highest photopic sensitivity; (B) the perifovea with a radius of around 10° where photopic thresholds increase with eccentricity; (C) a performance plateau extending to around 20° vertically and 35° horizontally where the dashed circle shows the nasal border; (D) peripheral field where thresholds increase up to the border of binocular vision; (E) monocular temporal border region. The two black dots are the blind spots. (Pöppel and Harvey, 1973)

Most people in modern technological societies rely extensively on foveal vision. We use to look at imagery on television and look at photographs and paintings. We use it to read facial expressions when talking directly to the person. When a person concentrates using this type of vision, they tend to ignore everything around the subject under focus (Danahy, 2001).

The foveal area of the retina is very small and relatively flat. That is why foveal vision cannot take in the complete scene; therefore its sensing requires a rapid, dynamic scanning and sampling of the objects in the landscape to build a cognitive model of the space. On the contrary the peripheral vision sensors cover most of the spherically shaped surface of retina and it provides a direct sensing of the complete scene (Danahy, 2001).

The peripheral vision system is also used to sense dynamic changes in the pattern or array of light arriving at the retina from the surrounding environment. One of its purposes is to “catch” one’s attention. Subsequently, one’s mental attention is directed to the foveal system to look directly at the perceived change in environment (Danahy, 2001). The peripheral vision system provides the cerebellum with information used to judge where a body is in space, which direction it is going, and at which relative speed (Ernst et al., 2000).

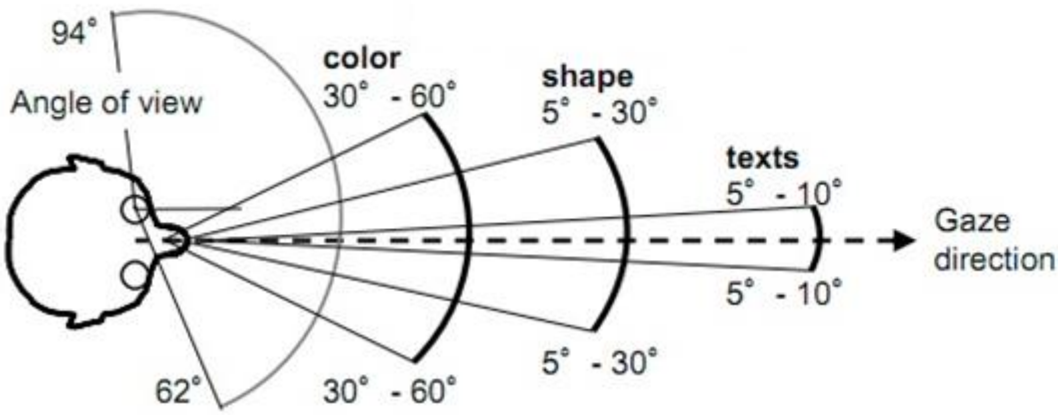


Figure 2. The recognizable angles for text, shapes, and colour of human eye (Komatsubara, 2008)

Peripheral vision also uses a different neural pathway to the brain than foveal vision and stimulates different areas of brain activity (Hilgard et al., 1975). This may explain why many people do not make conscious use of their peripheral vision without being disciplined or taught to do so (Danahy, 2001).

1.1.3 Visual processing

Visual sensory data pass from the eye to the primary visual or occipital cortex. Thereafter the information is processed in two principal locations, the temporal and the parietal lobes (Dutton, 2003). The temporal lobes contain "image libraries" and bring about recognition of what is being looked at. The posterior parietal lobes appraise the entire visual scene and interact with the frontal lobes in choosing the object of interest and planning appropriate visually guided movement. Recent research suggests that from a functional point of view there are two pathways, the dorsal stream, which links the visual cortex with the parietal lobes, and the ventral stream, which links the visual cortex with the temporal lobes (Milner & Goodale, 1995; Stasheff & Barton, 2001).

The posterior parietal cortex contributes significantly to attentional visual function. Severe bilateral posterior parietal pathology gives rise to simultanagnosia in which there is profound difficulty registering the presence of any object that is not being attended to. Affected individuals have an inability to interpret the totality of the scene despite a preserved ability to apprehend individual portions of the whole. Natural visual scenes are cluttered and contain many different objects that cannot all be processed simultaneously. Therefore, from an operational perspective, visual attention is a matter of organising multiple brain centres to act in concert to select relevant and to filter out irrelevant information.

Evidence from functional brain imaging suggests that attention operates at various processing levels within the visual system and beyond. The lateral geniculate nucleus (LGN) appears to be the first stage in processing visual information. In addition to retinal afferents, the LGN receives modulatory inputs from the striate cortex (mainly the V1 layer), the thalamic reticular nucleus (TRN) and the brainstem; it probably represents the first stage in the visual pathway at which cortical top-down signals affect visual information processing (Kastner, Pinsk, 2004).

Visual attention is not, however, an all or nothing phenomenon and there are many ways of both describing and quantifying it. Searching the visual scene involves both parallel and serial mechanisms (Duncan & Humphreys, 1989; Wolfe, 1994; Connor, Egeth & Yantis, 2004) The capacity to move effortlessly through the visual world has recently been argued to be subconscious, reflexive and remarkably accurate. Such preattentive vision does not entirely entail conscious analysis of the visual world and is a global visual function providing simple analysis of the whole scene in a parallel fashion. Foveation on the other

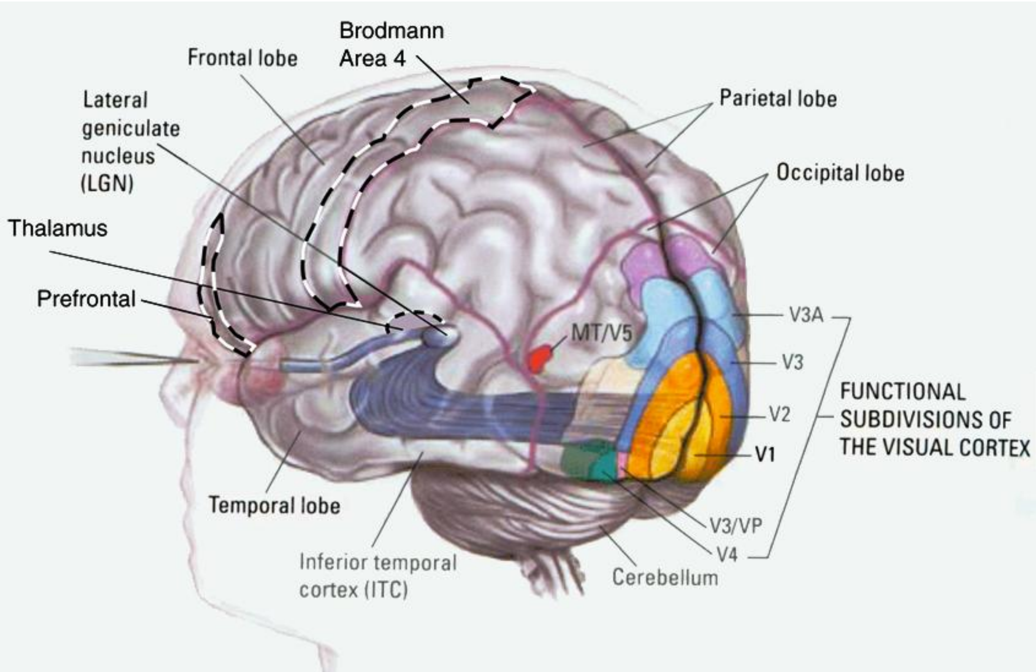


Figure 3. The lobes of the brain. Source: Fulton, 2000

hand requires sequential serial attentive mechanisms for the conscious analysis of the visual world. Pre-attentive vision is responsible for the phenomenon of “pop out” in which an element of the visual scene is sufficiently different from the background that it spontaneously stands out. Such differences include movement, colour and contrast. On the other hand, complex images such as faces and words require serial search to identify, and this constitutes a bottleneck in visual information processing, as this takes much longer to process (Davis & Palmer 2004; Wolfe & Horowitz 2004)

1.1.4 Eye tracking

Eye tracking is the process of measuring the point of or the motion of an eye relative to the head. An eye tracker is a device for measuring eye positions and eye movement.

The most widely used current designs are video-based eye trackers. A camera focuses on one or both eyes and records their movement as the viewer looks at some kind of stimulus. Most modern eye-trackers use the centre of the pupil and infrared/near-infrared non-collimated light to create corneal reflections (CR). The vector between the pupil centre and the corneal reflections can be used to compute the point of regard on surface, the gaze direction or fixation. Fixation or visual fixation is the maintaining of the visual gaze on a single location. A simple calibration procedure of the individual is usually needed before using the eye tracker (Witzner Hansen & Qiang, 2010).

1.2 ATTENTION

1.2.1 Visual attention

Attention is the behavioural and cognitive process of selectively concentrating on one aspect of the environment while ignoring other things. Attention has also been referred to as the allocation of processing resources (Anderson, 2004).

In cognitive psychology there are at least two models which describe how visual attention operates. These models may be considered loosely as metaphors which are used to describe internal processes and to generate hypotheses that are falsifiable. Generally speaking, visual attention is thought to operate as a two-stage process (Jonides, 1983).

Following James (1890), researchers have commonly distinguished between active and passive attention. The former is conceptualised as goal-driven and voluntarily controlled in a top-down fashion, whereas the latter is stimulus-driven and governed by bottom-up perceptual processes. Thus in foraging for food, mammals would rely on active, goal-driven processes, and in detecting threat, on passive, stimulus-driven attention. James (1890, pp. 416-417) included threatening events such as “wild animals,” “metallic things,” “blows,” and “blood” among stimuli likely automatically and reflexively to capture attention. In agreement with this distinction, there are experimental data suggesting a contrast between voluntary, effort-demanding attentional processes with a slow time course, and quickly dissipating selective processes that are rapidly and automatically activated by peripheral stimulus events (e.g., Jonides, 1981; Müller & Rabbitt, 1989). Here, we consider emotion to be fundamentally organized by two motivational systems, one appetitive and one defensive, that have evolved to mediate transactions in the environment that either promote or threaten physical survival (Lang, Bradley, & Cuthbert, 1997). The defence system is primarily activated in contexts involving threat, with a basic behavioural repertoire built on withdrawal, escape, and attack (Bradley et al., 2003).

1.2.2 Evolutionary motivation

Mammals evolved in environments where resources and dangers were unpredictably distributed in space and time. The reproductive potential of individuals, therefore, was predicted on the ability to efficiently locate critically important events in the surroundings. Resources such as food and mating partners were the objects of active foraging, whereas dangers had to be reflexively detected to be adaptively avoided. Framed in this way, an important component of the adaptive problem concerns different varieties of selective attention (Öhman, Flykt, Esteves, 2001).

1.2.3 Emotions

Emotional stimuli generate affective reactions and motivate appetitive or defensive behaviour, presumably because such stimuli represent events that have special adaptive importance for preservative or protective functions (Lang, Bradley, & Cuthbert, 1997). If this is so, our cognitive system must be motivationally biased to allocate preferential attention to emotional stimuli (Calvo & Lang, 2004).

1.3 PSYCHOLOGY OF ART

1.3.1 Art

Art is considered to be a subjective field, in which one composes and views artwork in unique ways that reflect one's experience, knowledge, preference, and emotions. The aesthetic experience encompasses the relationship between the viewer and the art object. In terms of the artist, there is an emotional attachment that drives the focus of the art. An artist must be completely in-tune with the art object in order to enrich its creation (MacCarthy & Sullivan, 2012). As the piece of art progresses during the creative process, so does the artist. Both grow and change to acquire new meaning. If the artist is too emotionally attached or lacking emotional compatibility with a work of art, then this will negatively impact the finished product (MacCarthy & Sullivan, 2012). According to Bosanquet (1892), the "aesthetic attitude" is important in viewing art because it allows one to consider an object with ready interest to see what it suggests. However, art does not evoke an aesthetic experience unless the viewer is willing and open to it. No matter how compelling the object is, it is up to the beholder to allow the existence of such an experience (Buckner & Sandelands, 2012).

Abstract paintings are unique in the explicit abandonment of representational intentions. Figurative or representational art is described as unambiguous or requiring mild interpretation (Landau, Greenberg, Solomo, Pyszczynski & Martens, 2006).

1.3.2 Neural evidence

Neuroanatomical evidence from studies using fMRI scans of aesthetic preference show that representational paintings are preferred over abstract paintings (Vartanian & Goel, 2004). This is displayed through significant activation of brain regions related to preference ratings (Vartanian & Goel, 2004). To test this, researchers had participants view paintings that varied according to type (representational vs. abstract) and format (original vs. altered vs. filtered). Behavioural results demonstrated a significantly higher preference for representational paintings (Vartanian & Goel, 2004). A positive correlation existed between preference ratings and response latency. FMRI results revealed that activity in the right caudate nucleus extending to putamen decreased in response to decreasing preference for paintings, while activity in the left cingulate sulcus, bilateral occipital gyri, bilateral fusiform gyri, right fusiform gyrus, and bilateral cerebellum increased in response to increasing preference for paintings (Vartanian & Goel, 2004). The observed differences were a reflection of relatively increased activation associated with higher preference for representational paintings (Vartanian & Goel, 2004).

A general trend shows that the relationship between image complexity and pleasantness ratings form an inverted-U shape graph (see Expertise section for exceptions). This means that people like increasingly like art as it goes from very simple to more complex, until a peak, when pleasantness ratings being to fall again.

A recent study had also found that we tend to rate natural environment and landscape images as more complex, hence liking them more than abstract images that we rate as less complex (Forsythe, Nadal, Sheehy, Cela-Conde & Sawey, 2011).

1.4 CHANGE BLINDNESS

Change blindness is a surprising perceptual phenomenon that occurs when a change in a visual stimulus is introduced and the observer does not notice it.

Research on change blindness developed from investigation in other phenomena such as eye movements and working memory (Simons & Levin, 1997). Although individuals have a very good memory as to whether or not they have seen an image, they are generally poor at recalling the smaller details in that image (Nickerson & Adams, 1979; Shepard, 1967).

The laboratory study of change blindness began in the 1970s within the context of eye movement research. McConkie conducted the first studies on change blindness involving changes in words and texts; in these studies, the changes were introduced while the observer performed a saccadic eye movement. Observers often failed to notice these changes (McConkie & Rayner, 1976).

The development in change blindness research was able to show the effects of change blindness in more realistic settings (Simons, 2000). Additionally, further research stated that rather large changes will not be detected when they occur during saccadic movements of the eye. Another finding based on similar studies stated that a change was easily picked up on by participants when the eye was fixated on the point of change (Henderson, 1997). Therefore, the eye must be directly fixated on the area of change for it to be noticed. However, other research in the mid-1990s has indicated that individuals still have difficulty detecting change even when they are directly fixated on a particular scene (Simons, 2000).

Other researchers have discovered that mental processing in change blindness begins even before the change is presented. More specifically, there is increased brain activity in the parietal-occipital and occipital regions prior to the emergence of a change in a change blindness task (Alvaro, Pazo-Alvarez, Capilla & Amenedo, 2012).

Researchers have also indicated there is a difference in brain activity between detecting a change and identifying change in an image. Detecting a change is associated with a higher ERP (Event-related potential) whereas identifying change is associated with an increased ERP before and after the change was presented (Busch, Fruend & Herrmann, 2010).

Another recent study looked at the relation between expertise and change blindness. Physics experts were more likely to notice a change between two physics problems than novices (Feil & Mestre, 2010). It is hypothesized that experts are better at analyzing problems on a deeper level whereas novices employ a surface-level analysis. This research suggests that observing the phenomenon of change blindness may be conditional upon the context of the task.

1.4.1 Factors influencing change blindness

Age has been implicated as one of the factors which modulates the severity of change blindness. In a study conducted by Veiel et al. it was found that older individuals were slower to detect the changes in a change blindness experiment than were younger individuals (Veiel, Storandt & Abrams, 2006). This trend was also noticed by Caird et al., who found that drivers aged 65 and older were more prone to making incorrect decisions after a change blindness paradigm was used at an intersection, than were participants aged 18–64 (Caird, Edwards, Creaser & Horrey, 2005).

Attention is another factor that has been implicated in change blindness. increasing shifts in attention decrease the severity of change blindness (Smith & Schenk, 2008) and changes in the foreground are detected more readily than changes made to the background of an image, an effect of the intentional bias for foreground elements (Veronica, Massimo & Carlo, 2005).

1.5 STATE OF ART

1.5.1 Contrast thresholds for character recognition

First measurements of contrast thresholds for peripheral form recognition were performed with the Tübinger perimeter using a diamond vs. circle discrimination task (Aulhorn, 1960, 1964; Aulhorn & Harms, 1972; Johnson, Keltner, & Balestrery, 1978; Lie, 1980) and by Fleck (1987) for characters displayed on a computer terminal. Herse and Bedell (1989) compared letter contrast sensitivity to grating contrast sensitivity at 0°, 5°, 10°, and 15° in two subjects on the nasal meridian. Eccentric viewing resulted in a larger sensitivity loss for letters than for gratings.

Strasburger and Rentschler (1996) included further measurements of letter contrast thresholds on the vertical meridian and standard static perimetry in the same subjects to compare visual fields defined by letter contrast sensitivity, on the one hand, with those defined by light spot detection, on the other hand. The results showed that at any given threshold contrast the visual field of recognition is much smaller than the perimetric field of detection (*Figure 4.*) (Strasburger & Rentschler, 2011).

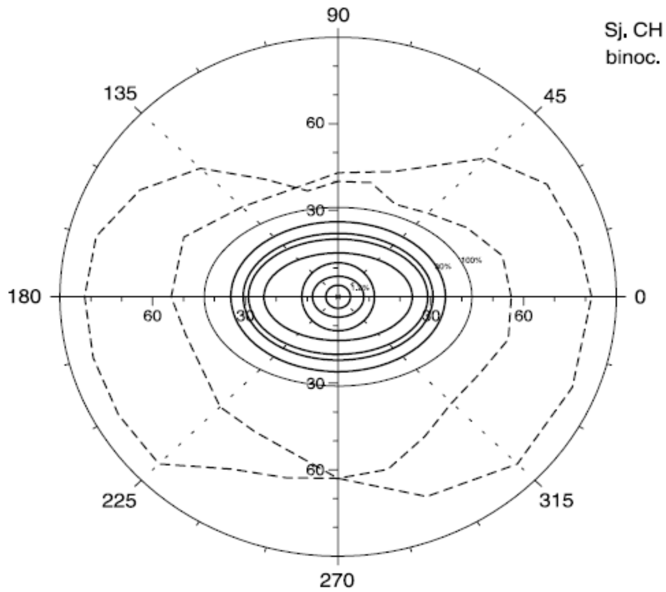


Figure 4. Visual fields of recognition and detection for one subject (CH). The form of the field is approximated by ellipses. Each ellipse shows the border of recognition at a given level of contrast, at the values 1.2%, 2%, 3%, 4%, 6%, 10%, 30% starting from the inner circle (contrast in Michelson units). Note the performance plateau on the horizontal meridian between 10° and 25° (between the 3% and 4% line), similar to the one found in perimetry (Harvey & Pöppel, 1972; Pöppel & Harvey, 1973). The 100%-contrast ellipse represents a maximum field of recognition obtained by extrapolation; its diameter is 46° x 32°. Also indicated in dashed lines are the fields of light-spot detection in standard static perimetry for the same subject. (From Strasburger & Rentschler, 1996, Figure 4.)

Contrast thresholds were measured using a staircase procedure. In each trial, one stimulus which the subject had to identify in a 4-AFC procedure was shown for 500 ms. Similar to the findings of Hübner et al. (1985) for faces and Strasburger et al. (1994) for letter-like stimuli pure size scaling proved insufficient to equate foveal performance in peripheral vision. As in the study by Strasburger et al., such equivalence could be only be obtained by increasing both size and contrast. In a second experiment involving the identification of the face stimuli in two-dimensional spatial noise, the peripheral inferiority was found to be the result of a reduced efficiency in the use of contrast information for pattern matching rather than the consequence of an eccentricity-dependent attenuation in the peripheral retina and subsequent visual pathways.

Martelli, Majaj, and Pelli (2005) presented the stimuli for 200 ms in the right visual field and with eccentricities of up to 12 deg. In each trial, the subject had to identify a target stimulus (one of five letters or one of three mouths, respectively). For peripheral vision, the presence of context features led to similar impairments, regardless whether the target was a letter or a mouth (taken from a photograph or caricature). In a further experiment involving words and face caricatures only, the impairments could be compensated for by increasing the distance of the target features (letter/ mouth) from the rest of the stimulus

1.5.2 Crowding effect

In peripheral vision, the recognition of detail is radically impeded by patterns or contours that are nearby. This phenomenon is known (or has been studied) under a number of terms *crowding* (Ehlers, 1953; Stuart & Burian, 1962), *contour interaction* (Flom, Heath, & Takahaski, 1963; Flom, Weymouth, & Kahnemann, 1963), *interaction effects* (Bouma, 1970), *lateral inhibition* (Townsend, Taylor, & Brown, 1971), *lateral interference* (Chastain, 1982; Estes, Allmeyer, & Reder, 1976; Estes & Wolford, 1971; Wolford, 1975), *lateral masking* (Geiger & Lettvin, 1986; Monti, 1973; Taylor & Brown, 1972; Wolford & Chambers, 1983), *masking* (Anstis, 1974), and *surround suppression* (following V1 neurophysiology; Petrov, Carandini, & McKee, 2005).

The main findings of the study of Strasburger and Rentschler (2011) were:

1. The crowding effect, as measured by a changed target contrast threshold, stems partly from whole-letter confusions with a flanker and partly from other sources

2. The cue has a gain control effect on contrast thresholds, but the cue has no effect on positional errors

3. The gain control effect is highest with flankers at a relatively close distance. These functions scale with eccentricity, i.e., are similar in shape but are shifted to larger flanker distances with increasing eccentricity.

4. The cueing effect on target threshold contrast is independent of cue size.

2 DESIGN

2.1 AREA OF PERIPHERAL VISION INVOLVED IN COGNITIVE PROCESSING

The peripheral field of vision comprehends the majority of human field of vision, but it is not able to process everything that it sees in perfect detail. Therefore, if we wanted to study the processing of visual perception inside the peripheral field of vision influenced by the top-down information processing, first we needed to determine the size of the field that is still able to recognise the individual objects in the scene.

Based on the findings that the whole visual field, the fovea, perifovea or peripheral field are of elliptic shape, we hypothesized that the area of peripheral vision we are interested in, will also have the approximate shape of an ellipse. As the participants were supposed to use naturally both eyes, this ellipse was to be of broad shape - the major axis should lie horizontally and minor axis vertically.

For the obtaining of the radius of this ellipse we had thought up the experiment during which we shown to participants series of stimuli by showing one stimulus at the time. All stimuli were spread over the computer screen and were displayed only for a short amount of time. Before each stimulus, the participants were primed by fixation cross to look to the middle of the. After the stimulus we asked the participant whether he has seen the stimulus or not, and if he saw it he was supposed to answer what kind of stimulus it was. We expected that after the analysis of data we would be able to determine the field in which the most of the successfully distinguished stimuli were located.

In the next part of the experiment we were going to work with the changes on the snapshots and paintings, thereby we were not interested in the detecting the exact letters, more complicated symbols or emotions but objects. As *Figure 2.* (Komatsubara, 2008) indicates, this area should have much larger size than the one that is able to differentiate the text. Therefore, we chose to use three basic shapes for stimuli: circle, square and triangle. These stimuli are very simple and easily recognisable already by the primary visual cortex.

As the researches on contrast threshold for recognition of characters, shapes and faces (Herse and Bedell, 1989; Strasburger and Rentschler, 1996;

Mäkelä et al., 2001) show, the peripheral vision is inferior to foveal vision in recognition of distinguishing differently contrasting stimuli. We wanted to add the property of contrast to our stimuli to test this phenomenon by ourselves. Therefore, we decided to create the stimuli in two colour variations, one with lower and one with higher contrast to the background. We were interested whether the stimuli with lower contrast would form the different ellipse than the stimuli with the higher contrast. The stimuli with the higher contrast were white and the ones with lower contrast were red, both on a gray background.

We decided to test more sizes of stimuli to get results that are more detailed. We wanted to create the final ellipse by the combination of the ellipses that would be created by successfully distinguishing the shapes of the same size.

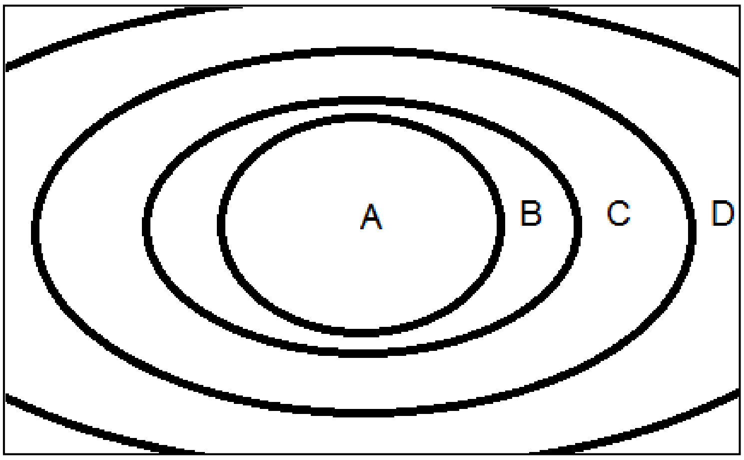


Figure 5. The scheme of presumed approximate ellipses where could happen the most of the correctly distinguished stimuli fitted into the size of computer screen. A is the ellipse created on the basis of the smallest stimuli, B, C, D are larger and larger stimuli. The D ellipse is so large that it exceeds the edges of computer screen, so we would know that the size of stimulus is too large for our purposes.

To determine the ideal size of the stimuli we needed to run few pre-tests. We created few images with the single stimulus of various sizes starting with size of 1 cm and the largest stimulus was 5 cm. These sizes were tested when they were randomly distributed over the screen, but especially on the edges. We found out that the sizes of 4 and 5 centimetres were unnecessary large and also that the smallest stimulus should be smaller than 1 cm. Finally, we decided to vary the basic shapes in the sizes of 0.5 cm, 1 cm, 2 cm, and 3 cm; for circle, it was the size of its diameter, for the square and for the equilateral triangle, it was the length of their side. During these pre-tests we have also tested the ideal length of the stimuli display time and decided on basis of previous research (Eriksen and Collins, 1969) for 60 ms; that was interval short enough to prevent a successful saccade to the stimulus (the movement of focus of the eye towards the stimulus).

From the Larson & Locschky's (2009) experiment with the two conditions: a "Window," a circular region showing the central portion of a scene, and blocking peripheral information, and a "Scotoma," which blocks out the central portion of a scene and shows only the periphery, we took their result of critical radius of 7.4°- that was found where the Window and Scotoma performance curves crossed, producing equal performance. We used this radius to determine the minimal distance of stimuli and later the changes, from the centre of the image.

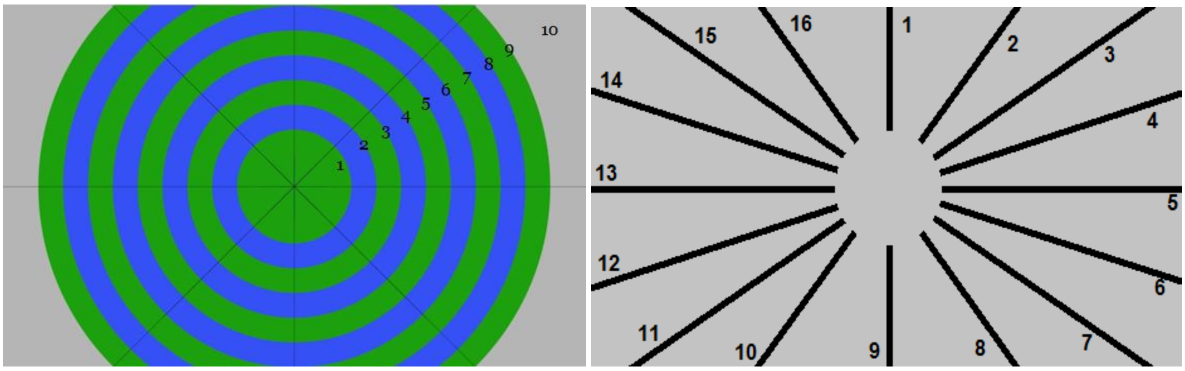


Figure 6. Left: 9 circles of distribution of the stimuli, the area in the middle was omitted. The exact position of stimuli was on the edge between green and blue field. All gray area was region number 10.
Right: 16 directions of stimuli distributions. The stimuli were distributed exactly on the lines or close to the lines, but not in the indistinguishable regions in between.

Based on this minimal distance we decided to create the template of widening circles with the common centre in the middle of the image, where the diagonals cross each other. The image was of the size of the computer screen we were going to use. Every next circle was larger than the previous one for about the same distance. *Figure 6. - Left* shows the 10 circles we have created this way.

To distribute evenly the shapes around the screen we decided to use the template of 16 lines that represented different positions that we mapped to the image with radiuses (*Figure 6. - Right*). Every shape was to be put approximately on the direction line and on the edge of its own circle.

This number of positions was able to cover effectively the whole image with stimuli. However as we calculated the number of stimuli we would get by this placing, we considered it too large (1280 stimuli), so we decided to reduce it.

We adjusted the two neighbouring circles in the way that into each we put only a half of the stimuli. Every second odd circle had the stimuli on the odd positions and the other one had them on even positions. The same was applied on even circles: every second even circle had the stimuli distributed on even positions and other one had them on odd positions. For a better idea, see *Figure 7*.

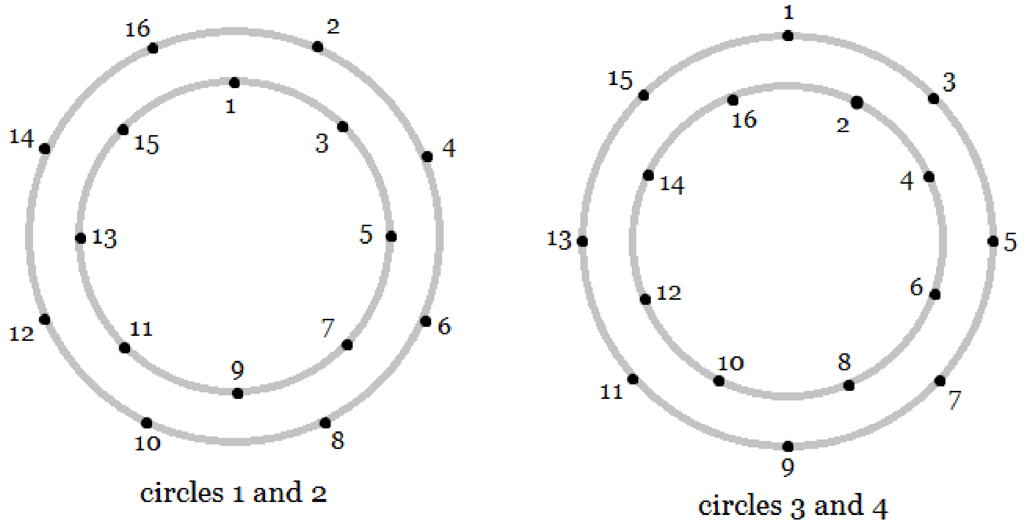


Figure 7. The scheme of stimuli distributions shown on two neighbouring circles, in the first category were the pairs of circles number: 1 and 2, 5 and 6, 9 and 10. The rest was in the second category.

Another way to decrease effectively the amount of stimuli was the redistribution of different sizes of shapes. We assumed that smaller shapes would be recognised worse than larger ones, especially even more as they were situated closer to the edges of the screen. Consequently we distributed the smallest shapes on all circles except the last area on the edges, where we reduced their number, because as we tested during the deciding the size of stimuli they were not efficiently recognisable in this area. Every other size was distributed accordingly: stimuli of size 1 cm were distributed from the circle number 2, stimuli of size 2 cm from circle 3 and stimuli of size 3 cm from circle 4. The red shapes were distributed only for sizes 1 and 2 cm.

All three types of shapes were varied approximately the same number of times; same times within each circle and also on the direction lines in order to guarantee variability.

For the control purposes we added other shapes, consisting of both red and white colour. These shapes were simple schematic flowers with round middle. The purpose of them was to check whether the participants will be able to recognise them as something different than the usual shapes. We also added the empty image without any stimulus and the image with two shapes at once. Both the multi shaped image and empty image were to prevent the participant to fall into the stereotypical priming just on the main three shapes.

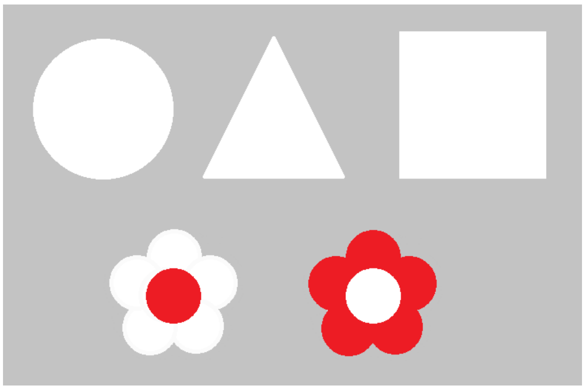


Figure 8. On the top are the shapes used for regular stimuli, on the bottom are the control stimuli shapes

We had assigned the exact position of each stimulus in our dataset (type of shape, radius, and number of position), so we could use this data for later analysis of results.

At the beginning of the experiment, we gave to every participant the questionnaire. Its purpose was to collect personal data about them that would help us during the data analysis to find possible correlations of them and the results of the experiment. The most important collected data were: the age of the participant, gender, the highest level of education and the dominant eye. Since we presupposed that something might get wrong during the run of experiment and it would show on the inconsistency of measured data, we added the question that asked about the actual tiredness of participant and whether he needs an aid for vision correction, and if yes, what kind.

Incidentally, the part of our participants was the Art School students, so we added a question whether the participants studied the history of art, also for the possibility of correlation.

2.2 PAINTINGS COMPARED WITH SNAPSHOTS

In the second part of our experiment, we used the field of peripheral vision that is still able to recognise the individual objects in the scene that we acquired during the first part. Now we were ready to study the possible influence of the top-down information processing on the difference in detection of changes on paintings and on snapshots.

The art paintings were selected based on different requirements. We needed to have a representational sample of several types of images: paintings, which displayed a dynamic scene, paintings with quiet scenes and landscapes. Another property that we took into account was complexity of the paintings; we tried not to use completely empty paintings, but at least with some elements in them, we also avoided the very complex paintings because the ability to recognize precisely the concrete objects in the scene would be rapidly decreased due to crowding.

Figure 9. The least complex painting (Albert Bierstadt - Sea Cove) and the most complex (Henri Gervex - The Club of the Ile de Puteaux) used painting.

Each of the paintings was visually recognizable and realistic; we did not use abstract or surreal paintings, although we used impressionistic pictures with less details and more vivid colours.

Very important part of the search for paintings was that we had to avoid the commonly known pictures. The problem we tried to avoid by this precaution was that if would participant see the change on the picture he knows, he might not truly notice the change; he might just remember what the changed thing should be from his previous experience with the painting. The risk of this problem to occur was even greater if the participant studied the History of Art.

Each of these images was paired with a snapshot that had been visually similar to it (colour, tone, arrangement), or with the similar content. We tried to find the snapshots that would not be considered as artistic photographs, but would rather show a realistic view of the world.

Figure 10. The painting of Alexander Max Koester – Duck Pond, and the snapshot with the similar content

We decided that the best type of change on the paintings and snapshots would be if something appeared or disappeared. It would be more naturally plausible change than that something changed colour. The problem with creating a change on this type of image was that it needed to seem real, like a part of the original, so the best way to arrange it was to remove object from the image.

The removed object was always outside the central area of the image (area 1 in *Figure 6. - Left*) and its size varied from 1 to 3cm. It was replaced with the background of the image or with the object that should be there if the object was not in the image in the first place, so that participants would not be able to detect the change by seeing inconsistency on the image.

For better variation of the changes, we created the three categories for them: 1st – something would appear on the image,

2nd – something would disappear from the image,

3rd – there would be no change at all.

We originally wanted to add a distracting element between the first image and the second with the change. Here we run into the problematic of change

Figure 11. The cropped part of a painting with a change – the head of the woman with blue headband was removed. Francesco Hayez - *The Sicilian* Vespers

blindness and that if we put a distracting image between the original and changed image, the participant would not even be able to detect the change, but would not be able to detect that there was a change at all. We needed to change the concept of stimuli presentation so that after the original image will be immediately shown the image with the change. The ideal length of the showing of first and second image was determined after few pre-tests.

At the beginning of the experiment, we gave every participant the questionnaire. This time it was also its purpose to collect personal data about the participants for finding possible correlations. Again, the collected data were: the age of the participant, gender and the highest level of education, the actual tiredness of participant, whether he needs an aid for vision correction, and if yes, what kind.

The very important question also stayed from the questionnaire from the previous part: whether the participant studied Art History. This time it was not just for the possibility of correlation, but it had protective function, so we could avoid the false positive responses based on the memory of the image.

3 IMPLEMENTATION

3.1 AREA OF PERIPHERAL VISION INVOLVED IN COGNITIVE PROCESSING

The experiment was created specifically for the equipment in the Laboratory for Cognitive Research in Art History at the University of Vienna: the size of the computer screen (Apple 30”), the type of eye tracking device (binocular remote eye-tracker SMI), and the distance of the participant from the screen (110cm).

All the images, the stimuli, guiding radiuses and distributing lines (*Figure 6.*) were created in Adobe Photoshop CS2. Every image of stimulus was in the format JPG and was set for high quality.

The size of all the images was 2560 x 1600 pixels, which was the whole size of the screen we were using for the experiment.

Based on our efficient redistribution of main stimuli shapes we created 192 different images: within each image was visible only one of the shapes, the radiuses and direction lines, as seen on *Figure 6. - Left* and *Right* were not visible for the participants. Similarly, we created the images with the control stimuli and empty images only with background. Together we created 210 images.

The presentation of stimuli was created in the program SMI Experiment Center 3.1 for eye tracker iView X RED 120Hz 2.0. The eye tracker was remote and contact free, so participants were not limited by discomfort. Before the final launch of experiment, we run several pre-tests and determined the ideal length of stimuli.

All participants were tested by Ishihara Test for colour blindness to select out the daltonic participants and after that they were tested for the far vision by taking the test to read the 2 cm numbers in the distance of 4 meters.

Before the experiment we needed to run calibration to set the eye-tracking machine for the exact participant; it needs to determine what the eye looks like when the participant is fixated on known locations on the screen. We used the red dot type of simulation, where the participant followed the red circle around the whole screen. The dot travelled from the middle of the screen (position 1 on the *Figure 12*.) along the line to the other positions marked with the number of its order. The participant fixates on 9 points on the screen while the eye tracker monitors the eye.

In some cases, the calibration needed to be repeated until we obtained the x/y axis error under 0.7 for both right and left eye.

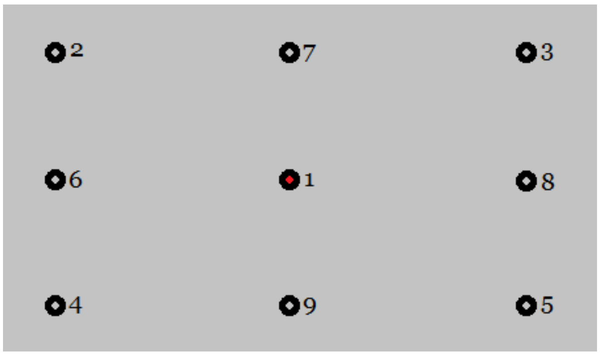


Figure 12. The calibration stimulus: the red dot passes through the positions in order to their numbers.

After the successful calibration in the beginning of the experiment itself, an information screen was shown to participant describing the instructions how to proceed. The participant was asked to look at the fixation cross when it appeared, not to move and do not talk during the presentation of stimuli.

The participants were also instructed not to guess the type of the shown form and only give the exact answers if they were sure of it. They were also asked not to visually search for the shapes and were assured that this was not the competitive type of experiment, because some of them were nervous beforehand that they were going to have bad results.

For the priming of participant to look to the centre of the image we let appear the fixation cross before each stimulus for 250 ms. It was 1.5 x 1.5 cm large and located in the centre of the screen where would the diagonals cross. It was the necessary step as we needed to have the area of focal vision pointed at the centre, so the stimuli were perceived in the peripheral vision. The stimulus appeared right after the fixation cross and it remained in a view for 60 ms. The stimuli were all randomized by the application.

Each stimulus was immediately followed by the question for the participant. Every question was the same and asked the participant whether he had seen a shape and if so, what form it was. The replies to the question were in the form of radio buttons, so the participant would not waste time by writing each reply. The options were:

- Circle
- Triangle
- Square
- I have seen a shape but I do not know which one it was.
- I did not see anything appear
- Other form
- There were more shapes at once

The options *Other form* and *More shapes* were for the control stimuli and the option I did not see anything appear was for the empty images, for the small stimuli on the edges of the screen that they did not catch and for the times when they were somehow distracted and didn't notice anything.

3.2 PAINTINGS COMPARED WITH SNAPSHOTS

The second part of research experiment was first created for the equipment in the Laboratory for Cognitive Research in Art History at the University of Vienna: the size of the computer screen (Apple 30''), the type of eye tracking device (binocular remote eye-tracker SMI), and the distance of the participant from the screen (110cm). In this environment, we measured 5 participants. As our access to this lab became limited, we needed to move our research to another. Here we replicated the environment, but due to the smaller computer screen (23'') we were forced to recalculate the size of stimuli images and the distance of participant to the screen (82cm).

We obtained the digitalised paintings from the Artstor Digital Library during our 120 day access period. Every painting had to fulfil the size and quality conditions: the minimal resolution had to be 2560 x 1600 pixels and the paintings must not have damaged surface. Often happened that the paintings were of good quality overall but they had destroyed edges from the frames; in these cases, we cropped them. The photographs had to fulfil these requirements as well. We decided to create a set of 40 paintings and 40 photographs.

We took the ellipse, that we acquired in the first part of the research, and mapped it on the image, so the centre of ellipse overlapped the centre of image.

Then we modified the images and created a dataset in which we recorded the images in which the change occurred inside the ellipse, where the change occurred outside of this ellipse and the ones where there was no change (*Figure 13.*).

Figure 13. The ellipse mapped on the image. The change happened inside the red circle, so the image would be categorised as "change outside the ellipse"

All modifications were done in Adobe Photoshop CS2. Every image of stimulus was saved in the format JPG and was set for high quality.

	Inside the ellipse	Outside of the ellipse	Very contrasting change	Smaller contrasting change
Images	20	10	14	16
Snapshots	23	17	16	14

Table 1. The distribution of different types of changes

The size of all the images was set to 2560 x 1600 pixels, which was the whole size of the screen we were using for the experiment. All the images were centred and if they were not wide enough the remaining space was filled by the gray background.

We put 15 paintings and 15 snapshots in the 1st and 2nd category, and in the 3rd category we put 10 paintings and 10 snapshots. The division of images between the 1st and 2nd category was done randomly.

In the first lab, the presentation of stimuli was created in SMI Experiment Center 3.1 for the same eye tracker device. All the conditions were the same as in the first part of experiment. During the sessions in the second lab everything was reduced to the resolution 1920 x 1200.

The ideal length of the stimulus presentation was determined after several pre-tests, as we had 80 stimuli, we didn't want the experiment last too long because we risked that the participants would lose interest or concentration. All the stimuli were set to be shown randomly.

All participants were again tested by Ishihara Test for colour blindness to select out the daltonic participants and for the far vision by taking the test to read the 2 cm numbers in the distance of 4 meters.

At the beginning of the measuring session in the first lab we run the calibration with the same conditions as in the first part of experiment. We also used the red dot as the stimulus and the maximal allowed error was 0.7.

Experiments in both laboratories had equivalent conditions and settings for the stimuli. The experiment started with the information screen describing the instructions how to proceed. The participant was asked not to move and not to talk during the presentation of stimuli, in case he had any questions he was asked to ask them later during the time for answering the question. He should look at the fixation cross and when the stimulus appeared, he should look at the same spot where the cross was until he noticed the change.

The participants were also instructed not to guess the object that changed and only give the exact answer if they were sure of it. They were again assured that this was not the competitive type of experiment.

Before every stimulus, the fixation cross appeared in the middle of the screen. The participants were instructed to look at the cross and when they were ready then manually press the button to continue with the experiment. After that the stimulus, which consisted of two parts, appeared. For the images of 1st category, where the change should happen by disappearing of an object, we first showed the unchanged image and after that the changed version. For the appearing of the object – 2^{nd} category, we first showed the changed image without the object and then the original version. For the third category, we showed the same image two times. The first shown image was displayed for 1000 ms and then showed up the second image for 5000 ms.

Every stimulus was followed by one or two questions (in case of paintings). The first question was asking the participant whether he saw a change and if yes, he was supposed to write down what exactly had changed. The second question was the control one and asked if the participant had seen the painting before. It was asked only in the case of paintings, because it was with minimal probability that participants had seen the snapshots before. It was important to ask this question, for the previously explained possible problem of correct answer on the first question not by correctly detecting the change, but by remembering how the original image looked like.

When emerged the necessity to change the laboratory, we made the precautions so that our experiment could be transferred to the lab without the eye-tracker device. We analysed the data from the first 5 participants measured in the first lab in Eye Trace 3.9.10. We were controlling on the images before the change, whether the fixations were made around the place where the fixation cross appeared.

During the pre-test, we set the fixation cross for the exact time in milliseconds, but participants were often distracted after answering the question, so they did not look exactly at it. After we set it to be executed manually, the participants had time to concentrate on the task and their fixations were around the middle. Therefore, we knew we could move the experiment with this type of setting into the other laboratory.

4 EXPERIMENTAL RESULTS AND ANALYSIS

4.1 RESULTS OF THE 1ST PART

The first part of experiment was attended by 20 participants: 6 men and 14 women. Ten of them were experts who studied art history and ten were non-professionals. Six participants had dominant left eye and the average age of participants was 26.7 years (the median was 26).

After the measuring, we gathered the results, created the dataset and processed it using three methods: we visualised the correctly/incorrectly differentiated data in the program Adobe Photoshop CS2, processed the data manually by sorting and filtering them and finally we analysed them through the data analysis and statistical software STATA.

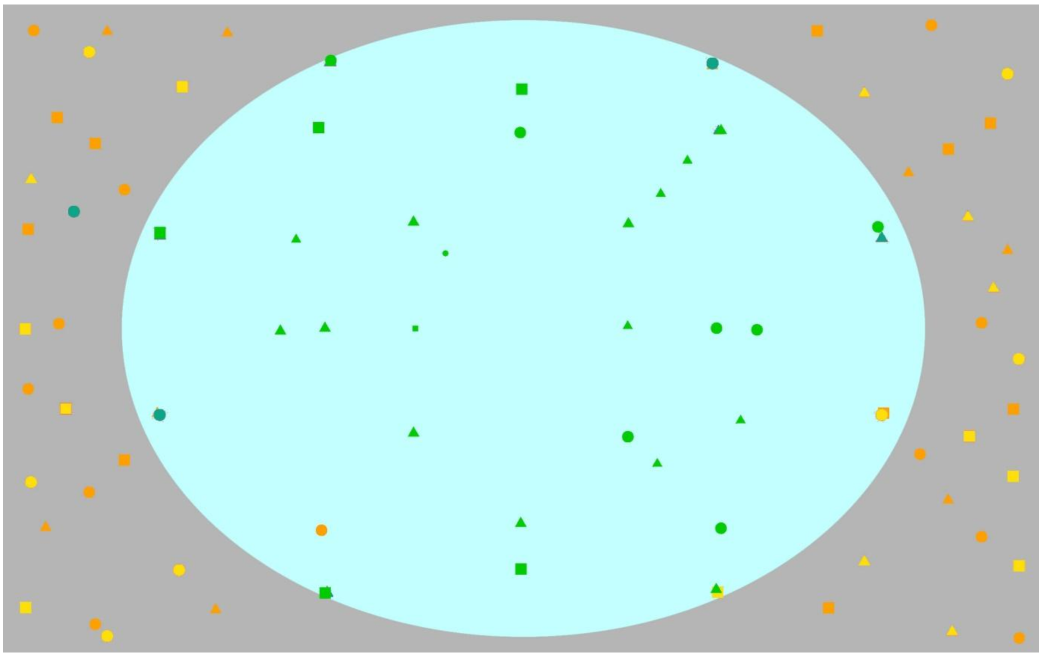


Figure 14. The resulting ellipse of vision that is involved in cognitive processing. The green stimuli are the most correctly recognised, the yellow/orange were not recognised, or were recognised wrongly. The dark green and yellow are originally the red stimuli (visualised only the most averagely recognised stimuli of size 0,5 cm and 1 cm).

By the combination of visually and statistically processed data we were able to determine the radius of the visual field. During visual processing, we took all images with basic stimuli and coloured them according to whether they were correctly recognised or not. By this method, the approximate ellipse visually emerged from the image (*Figure 14*).

The broad shape of the ellipse was supported by statistical analysis. We executed the logistic regression on the data to compare the successfulness of correct detection of stimuli according to their position on the distribution lines (*Figure 6. - Right*). We compared the stimuli on horizontal positions (4, 5, 6, 12, 13, 14) versus stimuli on vertical positions (16, 1, 2, 8, 9, 10). The correct detection of stimuli on horizontal position came up significantly more often recognised than on the vertical therefore the hypothesis, that the visual part, which is responsible for the cognitive processing, is the ellipse larger in width than in height, was confirmed.

The three graphs (*Graphs 1., 2., 3.*) show the number of participants that correctly distinguished the stimulus in comparison to the position of the stimulus inside the radius. As can be seen, the successfulness of distinguishing the stimuli is larger when they are closer to the centre of the screen. As the radius increases, the ability to detect the stimuli correctly lowers.

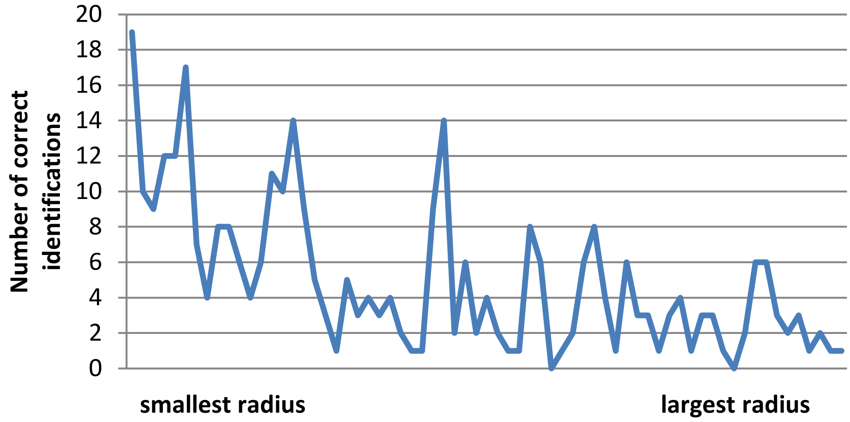
This phenomena is primarily seen in the stimuli of sizes 0.5 and 1 cm, the larger stimuli were detected with the small difference between radiuses.

The concrete successful rate for detecting stimuli according to their size was as follows in *Table 2.*:

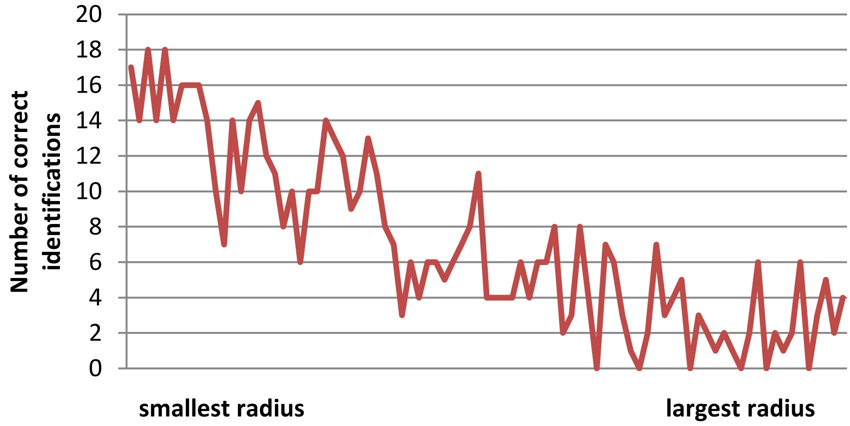
0.5 cm	24.6%
1 cm	35.1%
2 cm	86.6%
3 cm	91.9%

Table 2. The successful rate for detecting stimuli

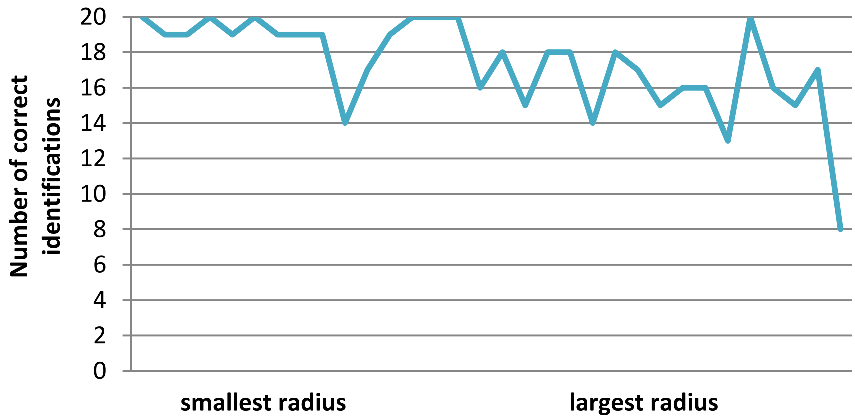
The circle was significantly better recognised than the other shapes. The reason probably is that this shape is the most simple in composition and is also the most naturally widespread in comparison to square and triangle, so the primary visual cortex was more likely able to recognise it.



Graph 1. The stimuli of the size 0.5cm, the ability of correct detection is lowering towards the edges of the screen.



Graph 2. The stimuli of the size 1 cm, the ability of correct detection is lowering towards the edges of the screen.



Graph 3. The stimuli of the size 2 cm, the ability of correct detection is lowering very slightly as the radius grows.

The analysis of more contrast (white) and less contrast (red) shapes had shown that more contrasting shapes were better recognised. The red shapes had 38.5% successful recognition from all red shapes, in comparison to white shapes that were recognised 54.5%.

The single controlling stimuli (the flower) were mostly not recognised at all (59%) or were mistaken (27%), mostly for the circles (72% of the mistakes). The second type of the controlling stimuli (the pair of stimuli shown at once) was successfully recognised as two forms in 80.6% of cases.

During the showing of empty background emerged the 15% error rate. The participants answered that they saw something; in 2.5% times they answered that, they saw the exact shape. The possible explanation is that they mistook the fixation cross for the stimulus, they were supposed to see, and in the second case, they simply guessed the form.

We got statistically significant results on the data set, that art experts had 10% more of successful differentiation of stimuli as opposed to the laity. It is possible that experience in their professional field provides them with greater ability of noticing and attention to detail. This theory could be supported by Feil & Mestre (2010).

There were not found any significant differences between the successfulness of recognition and therefore in size of the visual field of male and female participants, no important differences were found in the results for participants who had left or right dominant eye.

4.2 RESULTS OF THE 2ND PART

Within the pre-study, we found out that when the participants are directing the timing of execution of experiment themselves (they decide when they are ready to continue with experiment), they usually looked at the fixation cross and after that to the middle of the image that appeared. Therefore, we determined that the ellipse we obtained in the previous part of research might have its centre in the centre of the image.

This part of experiment was also attended by 20 participants: 9 men and 11 women. The average age of participants was 30.3 years (the median was 27). Originally, we wanted more participants, but the lack of financial reward and the length of experiment (35 - 50 minutes) discouraged the most of them.

During the result analysis, we put all the answers together and determined the correctness of the answers. We gave every type of result the value of its correctness, so the results could be determined in the way of getting average for every type of combination of variables.

We gave the correct answer for the stimulus value 1, the incorrect answer or the answer "*I have seen a change but I don't know what changed*" had value 2 and the answer "*I didn't see any change*" had value 3.

As there was no problem with the answers: 2 and 3, the determination of the exactly written answers was little problematic. As every answer written by participant in his own words, we needed to find the line where we still considered his answer as correct and when it was according to us not correct. When the answer on what changed contained the word "*something*", we automatically gave it value 2, because the participant saw something (sometimes they wrote very exactly that something changed on the window on the left), but was not able to tell what the thing that changed was exactly.

Sometimes, the participants did not know how to name the thing that changed, so they described it in their own words. In all these cases, we were able to identify the subject they were trying to describe and so we rated their answer according to the exact state.

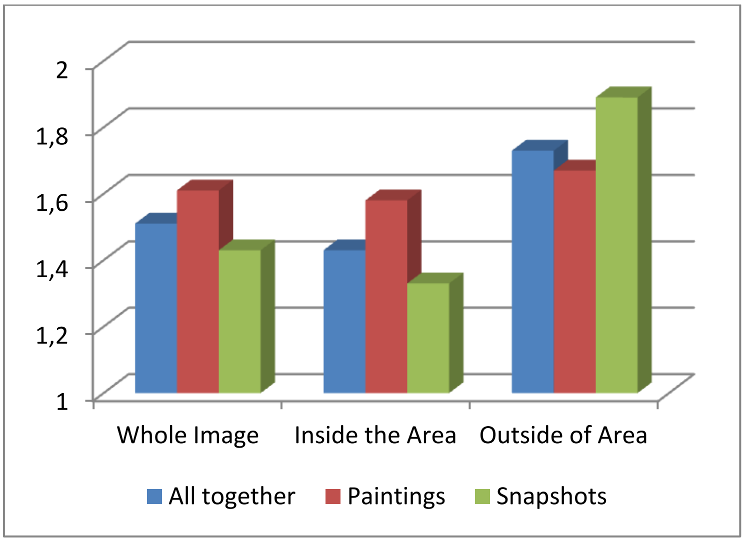
After we put together all the data, we used our method with averages of errors to determine the results. They are summarised in the *Table 3.* and *Table 4.*

	Paintings		Snapshots	
	Appeared	Disappeared	Appeared	Disappeared
Inside the Area	1.27	1.88	1.19	1.49
Outside of Area	1.56	1.81	1.8	1.98
Whole Image	1.39	1.86	1.3	1.56

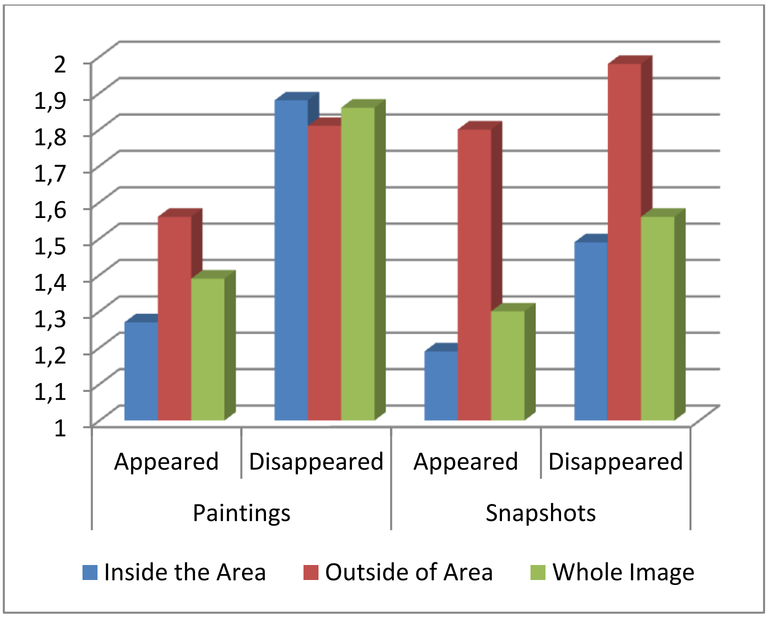
Table 3. Averages of error for the changes that appeared/disappeared in/out of ellipse

	Whole Image	Inside the Area	Outside of Area
All together	1.51	1.43	1.73
Paintings	1.61	1.58	1.67
Snapshots	1.43	1.33	1.89

Table 4. Averages of error that was calculated without the values of the answers for the stimuli without change.



Graph 4. *Averages of error for all the participants according to the changes that happened inside/outside the area of ellipse*



Graph 5. *Averages of error for all the participants according to the changes that appeared/disappeared inside/outside the area of ellipse*

As we can see from the results, the snapshots were better recognised than paintings, but only if the change happened inside the previously obtained ellipse. The ability to recognise changes in paintings does not fluctuate much, on the contrary to the snapshots.

As could be expected, the changes where something appeared were determined better than the changes where something disappeared. However as we can see on the Graph 5, there is again difference between the paintings and snapshots. The difference between the detection of appeared and disappeared stimuli for paintings is much larger than in snapshots, where are the differences almost the same for the changes inside the ellipse and outside of it.

The interesting fact emerged and it was the amount of false detection of change on the images where there was none. This false detection was almost the same for paintings and for snapshots. The participants did not say what exactly changed, so we assume it might have been the cursor of computer mouse that appeared on the screen.

From the written answers on the paintings, we resulted that the participants used to make up their own things that could be on the painting. They started to fantasise and completing the painting with the probable or improbable things, (the pink fan was mistaken for pink plumbing). On the contrary, when dealing with snapshots, they more often said they did not know what changed as they guessed.

We have noticed that the crowding sometimes occurred – if the single thing changed between the others, the most of the participants joined them together and answered that all of them appeared/disappeared.

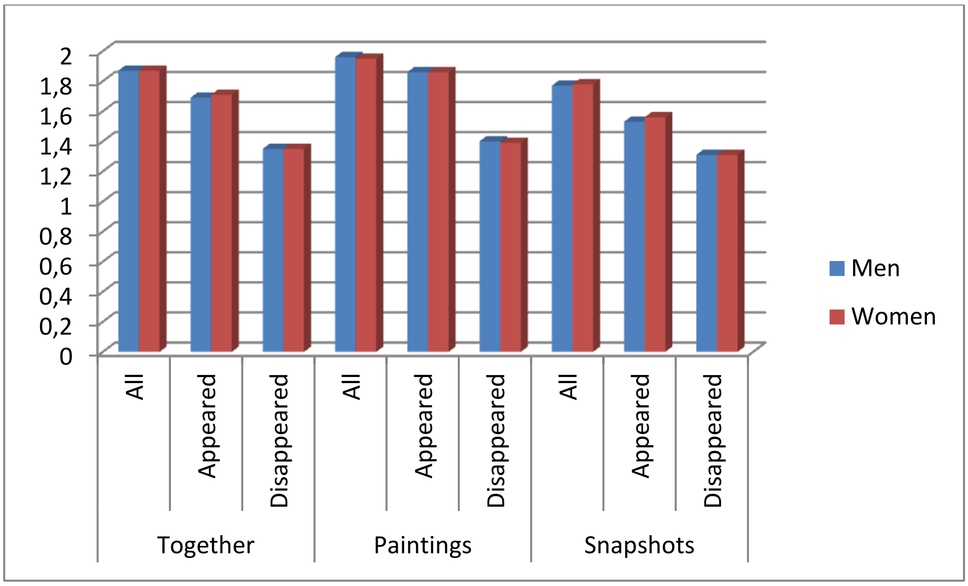
Sometimes the participants had problems with optical illusions that somehow happened. More of them wrote that they saw disappear the "white cloud" or "something white" when the change was green tree over the green background.

The simple and typical things were recognised more easily than complicated ones. The processing of the image in the visual cortex gives the answer for this type of stimuli much faster than for the unknown or untypical objects.

We also analysed the possible difference between the men and women. As the *Table 5.* and *Graph 6.* show, this difference was minimal, almost none.

	Men			**Women**		
	All Images	Appeared	Disappeared	All Images	Appeared	Disappeared
All together	1.87	1.69	1.35	1.87	1.71	1.35
Paintings	1.96	1.86	1.4	1.95	1.86	1.39
Snapshots	1.77	1.53	1.31	1.78	1.56	1.31

Table 5. *Averages of error compared between male and female participants.*



Graph 6. *Averages of error for male and female participants according to the changes that appeared/disappeared on paintings/snapshots*

4.3 FUTURE RESEARCH

Next step of the research might be the correlation of the level of creativity in participants to the amount of fantasised answers they incorrectly wrote. It could be interesting to know whether this creativity is typical for certain social group and if yes, what kind of results would this and another group would have on this type of experiment.

As we were limited by the necessity to change the lab, we were not able to record the results on eye-tracker and therefore check the resulting measurements for the possible problems. Every single image would need to be inspected, whether the fixations happened in the middle or not. Another move would be to expand the number of participants for the second part of experiment so the quantitative methods of statistics could be used to gain results that are more exact and to ensure the robustness of the statistical findings.

4.4 DISCUSSION

The possibility of the painting as the mediated filtered reality of the painter cannot be ignored. If the artist is not of hyper-realistic style, his paintings will always be visually just the abbreviation of reality. Everything they draw is less detailed than the real thing, so our brain needs more time to comprehend and understand it. If we look at the real ship on the se, we can see the huge amount of details that are typical for it, but when it is drawn, there might be only single stroke of brush as the sail. During the short amount of showing time, we might get many different results on what people see, but if we would give them time, they would surely say the correct answer.

Interestingly, it seems that the top-down processing seems to influence somehow our perception of images. We can see that as the participants started to fantasise around the paintings and acted more rationally when they were looking at photographs. The future research in this field might give us even the answer why.

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