The Aesthetic and Economic Value of Social and Non-Social Stimuli Seen from an Eye-Tracker:

Pupillary Changes and Eye Fixations can Index the Aesthetic Value of Human Faces as well as of Wine Labels

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I would like to dedicate the wine study of this thesis to my beloved country, Iran, where the wine was produced for the first time in recorded history, about 7000 years ago, and that has inspired many wonderful poets and artists. Although our people have been deprived from their true right to taste the rewarding value of wine, since the revolution of 1979, we hope to take our rights back!

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Table of Contents

Abstract

The present study examines the effect that hedonic value can have on economic decisions (e.g., willingness to pay) as well as oculomotor behavior and pupillary responses (i.e., measures of the allocation of attention). Due to the well-known interactions between reward circuitry in the brain, modes of activity in the LC, and pupillary dilations (Aston-Jone & Cohen, 2005; Laeng, et al., 2012), pupillometry with eye tracking should be a promising method to study the effect of hedonic stimuli. To our knowledge, no previous study has provided evidence that changes in the eye pupil's diameter can index parametrically the hedonic response (i.e., proportionally to the level of attractiveness of either social or non-social stimuli). Specifically, pupillary changes along with eye fixations of 49 participants were monitored while they were viewing images of either human faces or wine bottles. Both sets of stimuli had initially being rated by an independent group of 80 participants for their hedonic value. Participants made economic decisions by estimating either price or salary that participants would be willing to give for each wine bottle or person, respectively. Results showed a linear increase in pupil dilations in response to parametric increases in facial attractiveness, whereas non-linear, i.e. U-shaped, pupillary changes were registered in response to wine labels. Moreover, above median level of attractiveness in faces and wine labels triggered, respectively, smaller and greater numbers of eye fixations. The data from economic decisions revealed a linear increase in the level of offered monetary payoffs as a function of hedonic level for both faces and wine labels. Areas of interest analyses revealed the visual features that attracted the most attention and a left-side laterality effect. Finally, only facial attractiveness showed gender-dependent effects on both economic decisions and biological responses.

Introduction

Judgment and decision-making are among the major mental processes that humans need to engage in on a daily basis. The consequences of such decisions can have dramatic and long-term influences in an individual's life. Therefore, one of the most favored research domains in cognitive neuroscience is to characterize the factors that can influence our judgments and choices, and to detect the cognitive and neurobiological basis of (value-based) decisions (Rangel, Camerer, & Montague, 2008).

Rewarding stimuli are among the most influential factors in determining the final choices that we make. According to Berridge, Robinson, and Aldridge (2009), this effect comes from three psychological components of rewarding stimuli. That is, they induce (conscious or unconscious) pleasant feeling ('liking'), motivate reward-seeking behaviors ('wanting), and trigger association between positive feeling and approaching behavior ('learning'). In fact, reward-seeking is the core motivation in humans' behavior (e.g. making decisions) and has an adaptive role for survival (Atson-Jones & Cohen, 2005). In one study, Winkielman, Berridge, and Wilbarger (2005) presented happy faces (as rewarding stimuli) to a group of participants subliminally. Notably, they observed an increase in consumption behavior (drinking more beverage), willingness to pay (economic decisions), and wanting approach (attitude) in participants, without inducing any change in participants' conscious feeling.

1. Effects of Aesthetic Stimuli on (Value-Based) Decision Making

Objects with the hedonic and aesthetic value can have a strong influence on our judgments and decisions, because they can have a rewarding function (Leder, Belke, Oeberst, & Augustin, 2004). In fact, bodily attractiveness has been shown to impact significantly on our cognitive functions, from capturing attention, and inducing both better (or wrong) perception and better emotion, to biasing judgments, and determining our decisions. For example, Sui and Liu (2009) showed that presenting a task-irrelevant attractive face, even outside of foveal vision, impairs the covert attention needed for judging the orientation of a target.

The strong rewarding feature of attractiveness makes it very suitable to be used as an exemplar of salient and hedonic stimuli in order to investigate the mechanisms involved in processing rewarding and aesthetic stimuli. Therefore, not surprisingly, there exists a relatively well-established research literature as well as a variety of models regarding the causes and effects of attractiveness.

However, quite surprisingly, to the best of our knowledge, no study has investigated whether pupillary responses can index different levels of facial attractiveness. In addition, through pupillometry we can study gender interactions in processing facial attractiveness which have been previously found only by other behavioral and neurophysiological methods. Pupillary dilations may also be a reliable index of the activity of underlying shared brain areas involved in processing the attractiveness of both social and non-social stimuli (e.g., both faces and wine labels, which can be considered as exemplars of highly rewarding stimuli). Moreover, there has not been any investigation about the possible association between pupillary responses to attractiveness and following value-based, economic decisions. Finally yet importantly, no experiment has detected the location, number, and duration of eye fixations when freely viewing faces in order to make later economic decisions. These issues were investigated in this thesis.

In the subsequent sections, the objective will be to present the most promising theories and published behavioral, neuroimaging and pupillometry findings about different aspects of attractiveness as a rewarding event and its impact on our economic decisions. The neural basis of pupillary responses and eye movements are also explained in order to understand how pupillary responses can index the cognitive, neural, and aesthetic processes.

Effects of facial attractiveness

What are the influences of facial attractiveness on our judgments and decisions? Behavioral studies show that attractive people are perceived to have higher intelligence, social skills and health, indicating that there is a stereotype applied to them: 'what is beautiful is good' (Eagly, Ashmore, Makhijani, & Longo, 2001). People punish attractive children less (Dion, 1972) and attend more to attractive babies (Langlois, Ritter, Roggmann, & Vaughn, 1991).

In professional situations, attractive workers are paid up to 15% higher rates (Hamermesh & Biddle, 1994) and are wrongly attributed as being more able (Mobius & Rosenblat, 2006) than their unattractive peers, although it depends on the type of the job and the gender of the employee (Barbara & Taylor, 1988).

Attractive faces have a common effect. There are at least two fields of study which suggest that our biological heritage plays a role in forming these preferences for attractive faces, and therefore, these preferences are not just individually dependent tendencies. The first evidence comes from findings showing that these preferences emerge in the early stage of development before any cultural influences; in fact, even infants have already a preference for looking at attractive faces over unattractive ones (Salter, 1998). Other supporting evidence refers to general agreements about attractive faces between different cultures. Moreover, there is an agreement between men and women on their ratings for facial attractiveness (for either the same or the opposite-sex). These evidences indicate that beauty is not just in the eyes' of beholder; rather the attractive features per se have an aesthetic value that is universal (Langlois, Kalakanis, Rubenstein, Larson, Hallam, & Smoot, 2000).

What can be the adaptive reason for the strong effects of facial attractiveness? Evolutionary perspectives infer these attractiveness preferences as heritable traits (Fisher, 1915) or a signal of carrying 'good genes'' (Møller & Alatalo, 1999) that eventually signal the potential mate quality. Infants' tendency for, and universal agreements on attractive faces support the heredity account. The later attribution comes from evidence showing association between attractiveness and 'parental care', 'reduced risk of contagion' and 'heritable resistance to disease'. Zebrowitz and Rhodes (2004) found that attractiveness at the age of 17 associates moderately with later health but only for those who had a below median level of attractiveness. However, by-product theories claim that the general information processing mechanisms in the brain (not mate quality indicators) are the main evolutionary causes for forming the preferences for attractiveness. They point to the mechanisms involved in learning and generalizing the responses to the exemplars, and in abstracting category prototypes (Rhodes, 2006). For example, Halberstadt and Rhodes's (2003) study showed that average exemplars (as an indicator of attractiveness) are rated as more attractive in different category of objects, as well as human faces. Averageness, symmetry and sexual dimorphism are proposed as biological standards of facial attractiveness.

Undoubtedly, attractive faces are among the most rewarding stimuli in our environment, ones whose impact we all experience on a daily basis. However, the effect of attractiveness is not bound to the human faces. Attractive objects have also high rewarding value that can attract our attention and bias our choices.

Effects of attractive objects

What are the influences of attractive objects on our decisions? In one study, Tractinsky and Ikar (2000) showed that people think 'what is beautiful is usable'. They found high correlations between perceived attractiveness and perceived usability, both before and after using a computerized application. In another study, Chitturi, Raghunathan, and Mahajan (2008) investigated the effect of 'hedonic versus utilitarian benefits' of product design on consumers' post-consumption feelings. Results indicated that while design utility makes customers satisfied, hedonic designs increase customer delight, which improves their loyalty (purchase decision). Milosavljevic, Navalpakkam, Koch, and Rangel (2011) found that even relative differences in visual saliency can bias the consumers' choice and even override their preferences when they had to take decisions rapidly. Studies have shown that people are willing to pay more for the aesthetic aspects of things (e.g. Grala, Tyndall, & Mize, 2012).

What can be the cognitive and\or biological reasons for the hedonic value of aesthetic objects? Studies have shown that some features in objects can induce aesthetic and hedonic feeling (Sookyung, 2012). For example, unity (visual congruity between elements) and prototypicality (being representative of a category) can trigger aesthetic response when we look at new product designs (Veryzer & Hutchinson, 1998). Symmetry (similar to faces), complexity (Jacobsen & Hofel, 2002), averageness (Halberstadt & Rhode, 2003) and contrast (Ramchandran & Hirstein, 1999) are some other features inducing aesthetic values in objects.

Milosavljevic et al. (2011), reasoned that the effect of visual features come from this fact that the neurons at the retina and visual cortex are tuned for these simple properties. Ramachandran and Hirstein (1999) proposed an evolutionary account for the aesthetic features of paintings (e.g. form, depth, and color), claiming that the better perception of these properties are essential for survival in the environment. Khan, Dahr and Wertenbroch (2004) proposed a 'self-attribution model of the hedonic choices' to explain the reason of choosing hedonic, and not more utilitarian products. They speculated that, contrary to rational utilitarian theory (Kahneman, 1991), consumer behaviors in many cases are bound to their emotional wants and self-attributions drawn from their choices, rather than cognitive deliberations.

3. Cognitive Processing of Aesthetic Stimuli: Bottom-Up versus Top-Down

When an exogenous and salient stimulus can attract our attention automatically, irrespective of our conscious will, it is called bottom-up or stimulus-driven effect. Several studies have suggested that the perception of facial attractiveness is automatic, because it is processed effortless, rapid, and unconscious, and can influence cognitive performance (e.g. Olson & Marshuetz, 2005; Werheid, Schacht, & Sommer, 2007; Hooff, Crawford, & Vugt, 2010). Similarly, the visual saliency of some features (e.g color) in objects can have bottom-up effect to influence aesthetic experience (Zellner, Lankford, Ambrose, & Locher, 2010).

On the other hand, when our purposes and previous attitudes influence our perception of, and attention to the environment, it is called top-down processing. For example, individual preferences or cultural differences on the standards for beauty indicate an arbitrary role of top-down cultural conventions on our evaluations (Berry, 2000). Also, when we evaluate an option to take e.g. an economic decision we are applying a top-down process.

Some eye-tracking studies have shown that our visual behavior during observing paintings of objects, in comparison with paintings of human faces, is modulated more by bottom-up features rather than top-down processes like type of task (Massaro, Savazzi, Di Dio, Freedberg, Gallese, Gilli, & Marchetti; 2012). Nevertheless, studies have shown that the bottom-up effects of attractiveness can override the top-down purposes and affect our decisions regardless of being relevant to the task (Hamermesh & Biddle, 1994).

3. Neural Processing of Aesthetic Stimuli

Neuroimaging studies have provided intriguing findings about the neural structures involved in processing different level of attractiveness in both human faces and objects. The common hallmark of all results is the fact that attractiveness activates the reward circuitry (Senior, 2009), in particular within the orbitofrontal cortex (OFC) which is involved in processing the reward value of a wide range of stimuli (Rolls, 2000).

These findings are presented here in order to provide evidence for rewarding effects of attractiveness in both human faces and objects from neuroimaging studies. More importantly, these findings show that their rewarding values are processed in the same brain areas (e.g. OFC, ACC, mPFC) which have direct projections to the neural structures which influence the pupil diameter (e.g. Locus Coeruleus-Norepinephrine System).

Facial attractiveness

Brain reward circuitry is involved in perception and judging facial attractiveness. Functional Magnetic Resonance Imaging (FMRI) studies have shown that perception of facial attractiveness is associated with an increased activation in the orbitofrontal cortex (OFC) (Aharon, et al., 2001; O'Doherty, Winston, Critchley, Perrett, Burt, & Dolan, 2003), and the nucleus accumbens (NAcc) (Aharon, et al., 2001). Moreover, activation in OFC enhanced when the attractive faces smiled, which shows the increased reward value of the stimuli (O'Doherty et al., 2003). Judging faces as more attractive was also correlated with a linear increase in the mOFC activity, and more activation in medial prefrontal cortex (mPFC); anterior cingulated cortex (ACC) (O'Doherty, et al., 2003; Winston et al., 2007; Cloutier, Heatherton, Whalen, Kelley, 2008); and in superior temporal sulcus (STS) (O'Doherty, et al., 2003; Winston et al., 2007). While ACC plays role in learning level of attractiveness and monitoring internal states, STS's role is in more general judgments about the specific features of faces. A linear increase in women's' rOFC activity while judging faces as more attractive was associated with better later memory for those faces (Tsukiura & Cabeza, 2011b).

On the other hand, greater activation in the lateral OFC (involved in punishment and inhibiting negative affect) were found during judging faces as unattractive (O'Doherty, et al., 2003; Cloutier, et al., 2008), and a non-linear activation in amygdala in response to both the highly unattractive and attractive faces (Winston et al., 2007).

Aesthetic objects

The convergent neural structures (in reward circuitry) are involved when we perceive or judge the attractiveness of objects rather than human faces. As such, viewing beautiful paintings (Kawabata, Hideaki, & Zeki, 2003), and more beautiful dance movements (Calvo-Merino, Jola, Glaser, & Haggard, 2008), along with judging as more attractive the package designs (Stoll, Baecke, & Kenning, 2008), and geometrical shapes (Jacobsen, Schubotz, Høfel, & Cramon, 2005), was associated with enhanced activity in the reward system of brain (e.g. OFC, ACC, mPFC), and attention areas, which leads to more visual processing. However, it is suggested that areas like OFC and amygdala are 'selectively sensitive' to the level of attractiveness during just beauty judgments (Jacobs, Renken, & Cornelissen, 2012).

In contrast, looking at ugly paintings or judging package designs as unattractive were correlated with more activity in the motor cortex and in insula, respectively (Kawabata, Hideaki, & Zeki, 2003; Stoll, Baecke & Kenning, 2008). Insula processes the negative affective value and may mediate the automatic response to the aesthetic stimuli.

Distinct brain areas involved in processing social and non-social stimuli

Another informative field of research provided evidence for both shared and distinct areas in reward circuitry involved in processing social and non-social stimuli. For example, Philiastidesa, Bielea, and Heekerena (2010) observed a direct role of mPFC in computing the value of both faces and houses to take a value-based decision. However, different regions in the mPFC may be involved in the social and non-social evaluations; in fact, a greater activation in the anterior rostral (arMPFC) was seen during evaluating as positive just people, not objects,; while para-ACC showed sensitivity to the valence of both persons and objects. (Harris & McClure, 2012). Recently, Lin, Adolphs, and Rangel (2012) demonstrated that the same brain areas (vmPFC, OFC and ventral striatum) are involved during computing the values of both social and monetary rewards. However, different regions in these areas may be responsive, particularly, to each type of stimuli. Finally, it is suggested that the amygdala may have a 'domain-general' role in processing the motivational and emotional values, but, in humans, this role has evolved to be more sensitive to social stimuli (Adolph, 2003).

4. Sex-Dependent Effects of Facial Aesthetic

Behavioral studies have shown that in spite of general agreements on attractiveness judgments, there exist clear sex-dependent effects. Men show the highest levels of inter-consensus when rating the attractiveness of women, but not the attractiveness of men. Women's ratings, in contrast, are not significantly influenced by the sex of the target (Marcus & Miller, 2003). Moreover, men value attractiveness more than women (Feingold, 1990), and have higher self-satisfaction of their physical attractiveness (Feingold & Mazzella, 1998), but women's image of their attractiveness is more consistent with their real attractiveness as rated by others (Marcus & Miller, 2003). Gladue and Delaney (1990) found a time-dependent increase in ratings of attractiveness for only opposite-sex persons. Schulman and Hoskins (1986) observed that both men and women had higher level of 'idiosyncrasy' in their judgments of attractiveness of men but not for women. Gender differences were also found in the physical features that women and men considered as the most important indicators of attractiveness. (Pederson, Markee, & salusso, 1994).

There is also evidence of sex differences in the neural processing of attractive faces. For example, O'Doherty, et al. (2003) found more activity in the right vmPFC of only male subjects while watching the more attractive female faces. Moreover, anterior STS activity increased in both men and women in response to attractive faces in just opposite sex. Cloutier, et al. (2008) observed that only male participants recruited OFC, which may account for gender differences in considering specific attractiveness as rewarding. Additionally, Winston et al.'s (2007) study showed an increased activity in ACC of just male participants during perceiving attractive faces of both men and women, indicating a gender difference in arousal toward attractive faces. Nevertheless, Ishai (2007) found a three-way interaction between stimulus gender, attractiveness and the subjects' sexual preference (not gender) which contradicted the reproductivity account of strong tendencies toward attractive faces.

Taken together, these findings provide a plausible reason to expect that neurophysiological markers, e.g. pupillary responses, can index the effects of attractiveness.

5. Effects of Aesthetic Stimuli on Pupillary Dilations

The eyes' pupils have a light regulating role. Pupils have ability to both constrict from an average size of 3 mm (in standard light) to 1.5 mm (in intense light), and dilate to 9 mm in the dim light (Loewenfield, 1966). In fact, these fluctuations are determined by two iris muscles: 1) the sphincter pupillae, or circular fibers, which is under the control of parasympathetic system originated from Edinger-Westphal nucleus in the midbrain, and its contraction, under the intense light condition, causes pupillary constriction. 2) the dilator pupillae, or radial fibers, which is under the control of sympathetic system originated from hypothalamus, and its contraction, in relative dark environment, makes pupil to dilate (Andreassi, 2000).

Locus Coeruleus-Norepinephrin system

Cognitive and emotional events can also cause pupillary changes that often are around just 0.5 mm (Beatty & Lucero-Wagoner, 2000). Among the different brain areas that may have modulating influence on pupillary dilations, it is proposed that the attention driven-pupillary changes are, in fact, the result of norepinephrine (NE) secretion from the locus coeruleus (LC) (Laeng, Sirois & Gredebäck, 2012). The LC is a subcortical brain structure located in each side of rostral pons (see Fig. 1), and has an inhibitory effect on the parasympathetic oculomotor complex (Wilhelm, Wilhelm, & Ludtke, 1999). The LC is the only source of NE, and has projection to many important brain areas such as hippocampus, cerebellum, amygdala, cortex, and spinal cord. It is also innervated from several cognitive regions like the hypothalamus and cingulated gyrus, and from areas involved in processing rewarding stimuli such as the orbitofrontal cortex (OFC), anterior cingulate cortex (ACC), amygdala, and medial prefrontal cortex (mPFC) (Sara, 2009). Therefore, it mediates many cognitive and emotional processes.

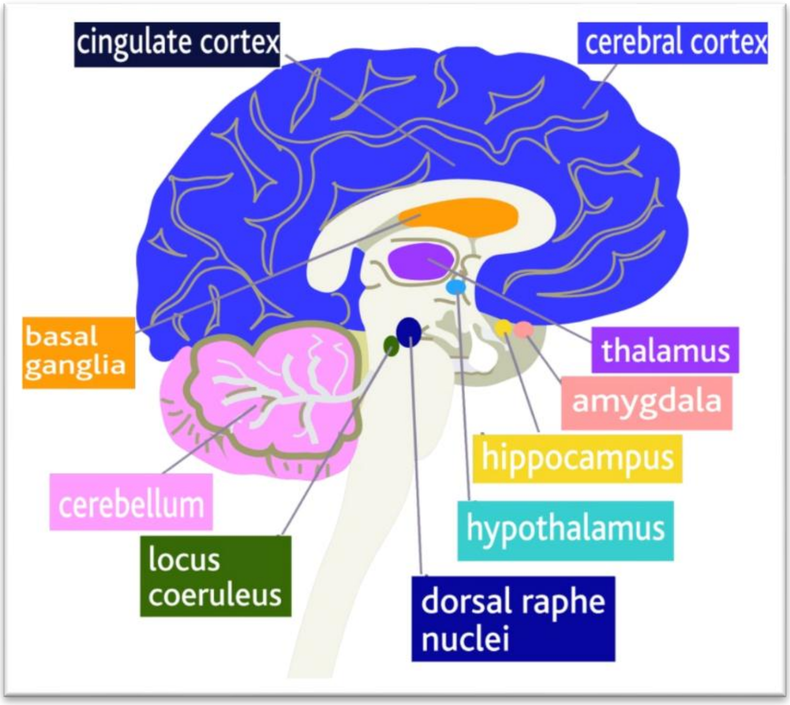

Fig. 1. Location of Locus Coeruleus in the brainstem

What is the role of LC? Studies recording the activation of a single neuron in the LC of monkeys have shown that the brain reward circuitry (e.g. OFC and ACC) has strong projections to the LC (Aston et al. 2002) which elicits two patterns of activity in the LC, called as phasic and tonic modes. The phasic mode of LC is associated with the onset of stimulus presentation (Rajkowski, Majczynski, Clayton, & Aston-Jones, 2004). In other words, during simple value-based decision-making, presenting the motivationally salient events such as the hedonic stimuli provokes the reward-Dopamine system. Inputs from ongoing evaluations of costs and benefits in the reward system drive the phasic mode of LC activity. This phasic activation releases NE at cortical sites responsible for task performance, so that we can focus our attention, process and follow the task-relevant events, optimize our performance during a specific task, and eventually exploit the existent rewards (Laeng, et al., 2012). However, according to gain theory (Aston-Jones & Cohen, 2005) the adaptive function of the LC is to optimize our 'reward-seeking behaviors' through its phasic and tonic modes to exploit and explore the reward sources.

How pupillometry can tap the LC's activity? As aforementioned, the LC modulates both cortical activities and pupillary changes. Therefore, through measuring the pupil diameter, many researchers have tried to track the cognitive processes and specifically the phasic and tonic activations in the LC-NE system. The result being that the phasic activation is associated with stimulus-related pupil dilations (Beatty, 1982a; Beatty, 1982b). In fact, the LC's strong influence on pupil size can override the effect of environmental luminance, and induce a reliable association between the online pupillary changes and two modes of LC-NE system (Koss, 1986). More importantly, although a voluntarily pupil dilation through imagination of a provoking object is possible (Whipple, Ogden, & Komisaruk, 1992), the suppression of pupil dilation caused either by external or mental events is not possible (Loewenfeld, 1993). The pupils' reactivity time can be as little as 0.2 s, with peak dilation in 0.5 to 1.0 s after presenting (especially strong emotional) stimuli. This shows a better temporal resolution in taping the underlying neural and cognitive mechanisms, in comparison with e.g. fMRI technique that lags the neural events triggering it by 1 to 2 s (Huettel, Song, & McCarthy, 2004). Laeng, et al. (2012) suggested that pupillary changes can reflect the shifts of our attention allocation and LC's modes even in a preconscious state.

Pupillometry can also track cognitive and emotional processes. From a literature perspective, in psychological research, the pupillary response was measured first by Hess and Polt (1960) to show the effect of emotional\ arousal stimuli which led to a 20% increase in pupil size during observing bodies of the opposite sex. However, after the publication of Kahneman's (1973) effort theory of attention, pupillary fluctuations have been frequently used as a neurophysiological indicator of both arousal and processing load or 'mental effort' (which again causes arousal) to tap the effect of task types and demands (Beatty, 1982b, Lang et al., 2012). Recently, Wierda, Rijn, Taatgen, and Martens (2012), using 'automated dilation deconvolution', applied pupillometry even in a 'fast-paced temporal attention task', to show the dynamics of attention during the fast conscious perception of stimuli (an approach which is contrary to the traditional assumption that pupillary reactions are only usable in slow tasks).

Pupillary dilations can index the aesthetic (hedonic) processing. Growing evidence has demonstrated that pupillary dilations also correlate with hedonic and aesthetic processing. Mudd, Conway, and Schindler (1990) observed an association between pupil dilation and the rating of musical segments as being liked. In contrast, disliking attribution was associated with pupil contraction. Laeng and Falkenberg (2007) found that women's pupils dilate when they looked at pictures of either their real or potential sex partner during their fertile phase of hormonal cycle. Higher pupillary dilations were also observed in response to more beautiful cubistic paintings (Kuchinke, Trapp, Jacobs, & Leder, 2009), and more beautiful car designs (Carbon, Hutziler & Minge, 2006).

As mentioned, surprisingly, we did not find any parametric investigation about the impact of facial attractiveness on pupillary responses. The only exception is Winston et al.'s (2007) fMRI study in which they aimed to measure also pupillary reactions but technical deficits hindered them. Nevertheless, their findings taken from 16 subjects showed increased pupil dilation in response to more attractive faces but only for male participants.

Notably, pupil size, in turn, influences our aesthetic evaluation, in an unconscious and gender dependent manner. That is, men typically rate female faces with larger pupil size as more attractive. In contrast, women prefer unconsciously men with the medium pupil size (Tombs & Silverman, 2004). Also, higher reactivity in amygdala is observed in response to faces with larger pupil size (Amemiya & Ohtomo, 2011).

6. Effect of Aesthetic Stimuli on Eye Fixations

Eye tracking. Eye movements' monitoring allows to measure eye fixations (where gaze dwells for a short period on a specific point or regions of the visual field), saccades (moving to another point) and blinks. An eye tracker device measures either the point of regard ('where we are looking') or the motion of eyes relative to the head. Video-based eye trackers are the most widely applied designs in which a camera records the eye movements while participants perform a task or simply look at some stimuli. Infrared light glittered from a dilator under the screen produces corneal reflections (CR). The vector between pupil center and the CRs is used to compute the gaze direction (Hansen & Ji, 2010).

Cause and function of eye movements. On average, eye fixations last 350 ms during the viewing of a scene, and provide most of the visual information which exists specifically inside the one or two central degrees of the visual angle (fovea). On the other hand, saccadic movements aim to provide foveal presentation of each small part of the environment in order to be processed with greater resolution. Our attention and gaze point change all the time when we are uncertain about the sensory information or behavioral outcome. Rewarding stimuli and our previous knowledge can also promote our orientation and gaze changes. Thus, duration and locations of eye fixations are quite informative in studying rewarding events and attention allocation (Henderson, 2006). In fact, according to the 'eye-mind theory' (Just & Carpenter, 1980) 'there is no appreciable lag between what is fixated and what is processed'. Therefore, eye movements can reflect which elements attract the attention, in what order, and how often.

However, eye fixations and saccades are not just random, passive manifestations of perceptual mechanisms; they have an active role in information processing, particularly in judgment tasks (Barton, Radcliffe, Cherkasova, Edelman & Intriligator, 2006). In fact, studies have shown that eye movements during facial recognition are not just a recapitulation of previously generated and learnt visual motions (Henderson, Williams & Falk, 2005).

The reciprocal relation between eye movements and aesthetic stimuli. Eye-tracking studies demonstrated that more beautiful computer graphics trigger greater number of eye fixations (Franke et al., 2008), people look at attractive faces longer than unattractive one (Shimojo, S., Simion, Shimojo, E. & Scheier, 2003; Leder, Tinio, Fuchs & Bohrn, 2010), and the effect of facial attractiveness on the visual behavior depends on gender of face and participants, and on the situational demands of the environment (e.g. threatening).

However, Shimojo et al. (2003) suggested that this implicit orienting behavior, i.e. gazing, can both reflect our preferences and contribute to the making of them. It means that gazing at both abstract shapes and faces leads to deeper sensory processing and a bias toward that stimulus to be chosen as more attractive (valuable). Furthermore, because this gaze bias is continually reinforced in attractiveness tasks, it leads to a preference formation, rather than merely a selection, which is called as 'gaze cascade effect'.

Can eye movements be informative in other domain of research as well? The use of eye tracking is not limited to research in psychology. Other domains like marketing and neuroeconomics also use eye tracking data in order to investigate the computational processes that people use to make decisions (Krajbich, Armel & Rangel, 2010; Krajbich & Rangel, 2011; Reutskaja, Nagel, Camerer & Rangel, 2011). Since our study involves also economic decisions, some findings from eye-tracking studies in this domain are here presented.

In marketing, the pattern of eye fixations has been used to detect the effect of display location, alternative set size, and visual features on final choice (Reutskaja, et al., 2011). Reutskaja, et al., (2011) found that participants chose the items that they looked at (fixated) first and more often, and were located in the center of the display. Russo and Leclerc (1994), using the pattern of eye fixations, proposed that consumer choice has a constructed and simplifying paradigm, consisting of three stages, ‘orientation’, ‘evaluation’, and ‘verification’.

7. Utilities of Wine Bottles as Aesthetic Stimuli

Italian wines are among the most well-known hedonic products across the world with high agreement about their quality and rewarding value (Marcis, 2011; Brentari, Levaggi, & Zuccolotto, 2011). Thus, like attractive faces, they are suitable and beneficial to be used as research stimuli in psychological, economic, and marketing studies. Therefore, there is a well-documented, yet still rudimentary research literature about the wine, wine bottles, and labels, as seen from marketing or psychological perspectives.

Behavioral studies have determined which elements convey the rewarding value of a wine, how people choose, and which factors have the most effect on their preference. For instance, the observable features and reputation drawn from the wine label had the biggest influence on the consumers’ willingness to pay (Combris, Lecocq & Visser, 1997). There are several variables one can infer from the wine label such as brand, appellation (presenting either the reputation, quality, type of grape, or maturation before selling), region of production, and alcohol content. Such information conveys a strong rewarding value for consumers, to the extent that they are among the most important determinants for wine prices (Brentari, et al., 2011). Appearance, particularly packaging, play also a very critical role in determining the wine price and consumer purchase (Mueller & Szolnoki, 2010; Barber & Almanza, 2006).

However, Atkin and Johnson (2010) clarified that there is difference in the label information that American consumers use to assess the rewarding value of wines when they have more knowledge about the wines. That is, wine experts pay more attention to the geographic information like the country and region of production, and vintage; but brand is often the most important criterion for all consumers. Moreover, they found gender differences in utilized information. For women it was the brand and illustration of label could attract women more. Interestingly, Boudreaux and Palmer’s (2007) study showed that people attribute ‘human characteristics’ to the wine brands. In addition, among different elements, the label illustrations had the greatest impact on both purchase will, and perceptions of brand personality. This result provides evidence for the effect of visual factors on preference formation, choices and economic decisions. Additionally, as aforementioned, an fMRI study showed how the price of wine affects people’s expectations about the quality and rewarding value of wine (Plassmann, et al., 2007).

8. Methodological Considerations

For the last 50 years, the measurement of pupil diameter (pupillometry) and eye movements have been successfully used to assess the intensity and changes in mental activities. Pupillometry by eye tracking can provide a continuous and quantitative measure of an externally observable response (pupil dilation and contraction) that is induced due to the unfolding cognitive processes in the brain (Laeng, et al., 2012). These task-evoked pupillary responses can reflect accurately the three criteria that any reliable physiological index should have; that means being able to demonstrate 'within-task', 'between-task', and 'between-individual' differences during 'mental effort' (Beatty, 1982b). Moreover, pupillary responses can be easily measured in a relatively inexpensive and non-invasive manner, regardless of participants' awareness or verbal abilities, which make it suitable for performing future comparative studies with different subjects and stimuli (Laeng, et al., 2012).

However, according to the previous findings some methodological points were taken into consideration in the present study. For example, photos of faces with direct gaze were presented to the participants, because it has been found that faces with direct gazes attract more attention, are seen longer and rated as more attractive by participants, irrespective of the task, or their background (Palanica & Itier, 2012).

Moreover, in spite of early detectable hedonic value of attractiveness, the presentation time was rather long in this study (10s), because long presentations could give us a better opportunity to identify the most frequently seen areas of either faces or wine bottles, since participants have enough time to change their gaze point freely. In addition, if a solely time-consuming effect induces pupillary dilations, then prolonged presentations make it possible to detect these effects (e.g. gender differences in pupillary responses to the faces were detectable when the stimuli presentation was long enough (3-7 s), Porter, Hood & Troscianko, 2006).

In addition, we used a remote camera eye-tracker in the present study because it can provide precise task-evoked pupillary responses, but in comparison to other types of eye-tracking devices, in a more comfortable manner (Klingner, Kumar & Hanrahan, 2008).

Finally, it is recommended to coupled the eye tracking with other methodologies, such as questionnaires (Holsanova, 2011), where participants can state explicitly what they were attending to in order to perform the task. Because according to 'covert attention theory' one can look at somewhere but attend to something else (Wrigth & Ward, 2008). In addition, the data taken from applying different experimental methods are more trustable than the data driven from each method alone. Therefore, a self-written questionnaire was also applied.

Current Study

As reviewed in the introduction, both faces and wine labels are very suitable stimuli in order to study the hedonic processes and value-based decisions. Due to the well-known interactions between reward circuitry in the brain, modes of activity in the LC, and pupillary dilations (Laeng, et al., 2012), pupillometry with eye tracking should be a promising method to study the effect of hedonic stimuli. However, to the best of our knowledge there is no eye-tracking or pupillometric research on wine labels. Most surprisingly, there are no pupillometry studies that have systematically investigated pupillary responses in relation to the effects of facial attractiveness.

Specifically, this study had the following four main purposes:

1) To investigate whether pupillary responses and eye movements can index different levels of attractiveness in either social or non-social rewarding stimuli (faces and wine labels, respectively).

2) To study whether attractiveness or hedonic value (of either faces or labels) has measurable and common (across stimulus type) effects on subsequent economic decisions.

3) To identify which visual features in faces or labels contribute to reward evaluations and the following economic decisions.

4) To discover and/or confirm the presence of gender differences in hedonic responses to faces and wine labels.

In order to answer the above questions, we presented pictures of both female and male faces, and of Italian wine bottles (according to a blocked design) to the same group of female and male participants (according to a within-subject design), while an eye-tracker apparatus recorded participants' eye fixations and pupil size. Separate groups of participants had previously rated the level of attractiveness for all pictures. These ratings were then used to categorize the pictures into four levels of attractiveness. To establish comparable testing conditions, despite the differences between social stimuli like faces and non-social stimuli like bottles of wine, participants were asked to perform tasks related to a same environment. That is, in the "face condition" they were asked to imagine that they were the manager of a Vinmonopol shop (i.e., a state-owned wine shop in Norway) and should decide how much salary they would be willing to give to a possible new employee in the wine shop. In the "wine condition", subjects were asked to imagine that they were a wine shopper in a same Vinmonopol shop and to decide how much money they would be willing to pay for a specific bottle of wine (see Procedure section).

Hypotheses

The main hypothesis was that all type of hedonic stimuli (social and non-social) are rewarding and, irrespective of task type, are processed by the same reward brain areas such as for example OFC. Reward computations in these areas during viewing attractive stimuli induce phasic mode of activity in the LC. Thus, we hypothesized that the higher levels of attractiveness in both faces and labels' design induce larger pupil size.

Moreover, according to Massaro et al. (2012) data, the paintings with human content, in comparison with nature content, trigger longer fixations couple to a fewer number of fixations. Therefore, we hypothesized that, opposite to wine labels, more attractive faces cause fewer but longer eye fixations. This expectation (fewer eye fixations in face condition) is also in accordance with holistically perception of faces (Tanaka & Farah, 2003).

Therefore, attractiveness was the independent variable and consequently pupillary responses, duration and numbers of eye fixations, along with subsequent economic decisions, were considered as the neurophysiological and behavioral dependent variables. Below we list the hypotheses that were specific to each condition of experiment.

In the investigation on facial attractiveness, we hypothesized that:

1) If faces can have high rewarding value, and if pupillary responses can index the level of attention allocation and arousal, then pupillary dilations should parametrically increase as a function of the level of attractiveness, during free viewing of the faces.
2) If more beautiful faces attract more attention, then more attractive faces are supposed to induce longer eye fixations (leading to fewer fixations within a specific period of time).
3) Moreover, if facial attractiveness depends on holistic perception, then more attractive faces should trigger fewer number of eye fixations.
4) If there exists a "beauty bias" that plays a role on the benefits that society is willing to give to the most beautiful individuals, then participants should willingly offer higher salaries to faces that are more attractive.
5) If there are gender-dependent effects in hedonic responses to facial attractiveness, then larger pupil sizes, together with longest and fewest number of fixations, will be evoked by the most attractive faces of the opposite sex.
6) In addition, if there are gender-dependent effects in economic decisions, then highest salaries will be assigned to the most attractive faces, especially of the opposite sex.

7) Face identification studies demonstrated that the eyes, nose and mouth are the most often viewed areas, respectively (Barton, et al., 2006; Schyns, Bonnar & Gosselin, 2002). However, it remains unclear which regions of the human face are important for hedonic judgments. Therefore, the present study may provide some insight on this unstudied aspect as well.
8) Moreover, if there is a left-side bias during the face scanning (Vinette, Gosselin & Schyns, 2004; Rossion, Joyce, Cottrell, & Tarr, 2003), due to either right-hemisphere laterality (Rossion, et al., 2003), or language-based biases (Heath, Rouhana, & Ghanem, 2005) in facial perception, then we expect to find it particularly between right-handed participants that their script direction is from left to right.

In the investigation on wine labels, we had the following hypotheses:

1) If pupillary responses can also index the hedonic value of labels design (as non-social stimuli), then pupillary dilations should increase parametrically with the level of the design's hedonic value when freely observing wine labels.
2) If more attractive designs attract more attention, then they would induce more numerous eye fixations in order to provide higher number of foveal presentations. This consequently, leads to shorter fixation duration in a specific time period.
3) If design attractiveness influences the economic value of productions (Combris et al., 1997; Mueller & Szolnac, 2010), then participants should be willing to pay more for more attractive designs.
4) If there are gender differences in scrutinizing visual stimuli, and in the information they use to choose wines (Barber, Dodd & Kolyesnikova, 2009; Atkin & Johnson, 2010), then these differing preferences should be detectable in fixation location and duration data taken from AOI analysis. In addition, there may be gender differences in the maximum amount they pay (Barber, 2010).
5) According to Massaro et al. (2012), bottom-up features (such as color) control the eye fixations during the assessment of objects versus faces. Moreover, Boudreaux and Palmer (2007) found that the label illustration had the largest impact on consumers' choice. Therefore, we predicted that illustrations would attract the longer fixations.

   In addition, we investigated some secondary hypotheses as followed:

6) If the participants' previous experiences and familiarity affect the pupillary responses, eye fixations (Russo & Leclerc, 1994; Henderson, 2006) and economic decisions, then we expect that familiarity with the subjective effects of drinking alcohol would cause even larger responses in alcohol consumers. Therefore, we recruited both participants

who consume alcohol, and those who nearly never drink alcohol to investigate whether there is any significant difference between these groups in dependent variables.

7) If there is a stereotype that 'what is more expensive, have higher quality and rewarding value (Plassmann, et al., 2007; Weber, Rangel, Wiberal, & Falk, 2009), then more expensive wines (in real market) will cause larger pupil size, more numerous fixations, and eventually a willingness to pay more money for them, particularly for the participants with relative familiarity with the wine prices. Thus, we sorted 10 different Italian brands in four different price levels to examine if subjects' responses were correlated with the real wine prices. To the contrary, if bottom-up effects of design attractiveness can override this up-down knowledge, our dependent variables will correlate only with the level of attractiveness of the label.
8) Finally, each brand was presented in four versions wherein one picture showed the real design in the market, while the other three pictures were foil labels of the same brand. In this condition, we had the opportunity to investigate whether the label that was selected for the market was actually also the one "preferred" (e.g. larger pupil, greater willingness to pay) by our participants, compared to the ones that had been discarded during the pre-marketing phase. Thus, if the real labels, compared to foil labels, can attract more attention, then they should induce larger pupil size and greater number of fixations. Moreover, participants will offer higher prices to the bottles with the real labels. To the contrary, if innovative designs make participants to attend more, and after prolonged exposure, enable them to rate those designs as more attractive (Carbon, et al., 2006), then we should observe that the foil labels induce a higher extent of our dependent variables.
9) Moreover, if there is a left-side bias during object scanning (Hsiao, Shieh, & Cottrell, 2008), then we expect to find longer fixations on the left side of the wine bottles, particularly between right-handed participants that their script direction is from left to right.

Methods

Participants

Forty-nine students (25 females; mean age, 25.6 years; SD, 6.1) from the University of Oslo participated, and received 100 Norwegian Krown (Kr) per hour. All participants had normal or corrected-to-normal (using eye contact lenses) vision, and signed a consent form prior to the experiment. No information regarding the main purpose of the study was revealed to them until testing was completed.

Material

Face stimuli. We used faces of differing attractiveness as stimuli. Face images were selected from a database of 208 color, close-up photos (114 females) provided by the photography department of the University of Oslo (Blindern) for research purposes. To do so, in a separate study, using E-prime software, we asked 41 participants (all of them were medicine students, mean age, 24.7; females, 21) to judge the facial attractiveness of each picture by clicking on a tab bar under each picture. After measuring the average of ratings on each image, the 114 female and 94 male images were sorted into four quartiles of attractiveness in separate groups for each gender (see Appendix 1 & 2). At the end, 80 final color pictures (40 females, 10 faces in each level) were taken from this data set while keeping same number of different hair and eye colors.

All of the faces showed a direct gaze, a neutral expression, and had no glasses. Each face had approximately the same size of 15 cm width and 20 cm height (i.e. about 530 × 710 pixels) at the center of a gray oval (27 × 29 cm) and, on average, equal to 8.5 degrees of visual angle. Such a visual angle would correspond to a face seen at a distance of about 100 cm, i.e. the approximate normal distance during conversation between two unfamiliar persons in Western societies (Henderson et al., 2005). The grey surrounding oval was, in turn, in the middle of a (29 × 39 cm) white rectangle, and presented at the center of a flat computer screen (29 ×47 cm). The equal lateral distances between the rectangle and screen (4cm) was again grey (see Appendix 3a). The distance of participants from the computer screen was 70 cm.

Wine stimuli. The other stimuli in the present study were 40 color pictures of Italian wine bottles provided by a Design studio, Doni & Associati (Firenze, Italy) for research purposes. As for faces, in a separate study, using E-prime software, another 40 participants were asked (all were students in law faculty, 20 females) to judge the attractiveness of wine bottles by clicking on a tab bar under each wine picture. Pictures were then categorized into four levels of attractiveness (10 wine bottles in each level) according to the quartiles of ratings (see Appendix 4).These 40 pictures consisted of 10 different brands of Italian wines with different prices (see Appendix 4). Thus, each brand was presented in four different versions. While one version shows the real label existent in the market, the other three versions belonged to the same wine brand and name, but with labels that have not been used commercially. The images of each wine bottle had roughly the same size, that of 5 cm width and 24 cm height (177 ×

851 pixels) and located at the center of a (29 × 39 cm) white rectangle, presented on the same computer screen at 70 cm distance (equal to 4.1 × 19.4 degrees of visual angle). As with the face images, the equal lateral distances between the rectangle and the screen was grey (see appendix 3-b).

Luminance-adjusted image slides. The influence of changes in ambient luminance is very important in pupillometry studies and was controlled in several ways in the present study. First, the experiments were performed in the same room (eye lab) where the only light source in the room was one fluorescent ceiling lamp which was on during all experiment runs, providing a constant environmental luminance. Second, three luminance-adjusted image slides were shown at the beginning of each trial, before presenting the test image (face or wine bottle), as explained bellow (see Fig. 2).

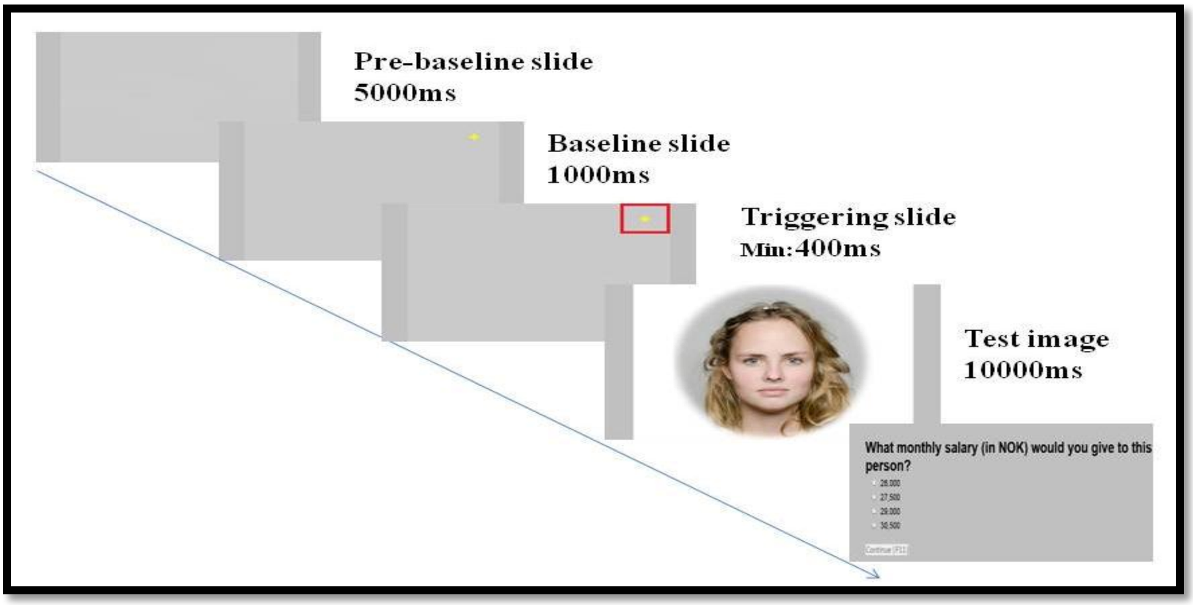

Fig. 2. An outline of the sequences in each trial of experiment and the luminance-adjusted slides

In every trail, the first shown photo (pre-baseline slide) was an empty gray (29 × 39 cm) rectangle presented for 5000 ms. The equal lateral distances between the rectangle and screen (4cm) was again grey. The luminance of this preparation slide was made equal to the average luminance of other images, and the purpose was to give time to the pupil to return to the rest level after performing the previous task (economic decision). The second luminance-adjusted image (baseline slide) was the same grey rectangle of the previous image, but included a yellow fixation cross (1.5 × 1.5 cm). The fixation cross was located in one of the four corners of the screen (in a pseudo-random sequence during the experimental block), so as to remove the gaze bias at the beginning of each trial to a central position (where the stimuli image would be located). These baseline slides were adjusted (by use of Photoshop software) to have an identical luminance as the subsequent stimulus picture. This procedure for luminance-accordance between the baseline and the test image was later tested by a “spyder 4 Elite” device, which measures the precise light output of the screen. Finally, the third luminance-adjusted image was a triggering slide that had the same luminance as baseline and test image. However, it also makes sure that subjects had gazed at the fixation cross for 400ms. Presenting these three luminance-adjusted images prior to test images made it more plausible to believe that pupillary responses across participants to each quartile are driven by our independent variables. Moreover, all the test pictures (faces and wine bottles) had the same photography format and were presented to all participants (in a within-subject design), ensuring that pupil dilations are not related to the different physical properties each stimulus can have.

Apparatus

A Remote Eye Tracking Device, (R.E.D.; SMI-SensoMotoric Instruments, Teltow, Germany), recorded the eye movements and fixations as well as pupillary responses in this study. The R.E.D. can operate at a distance of 0.5-1.5 m and the recording eye tracking sample rate was 60 Hz (meaning every 20 ms) with a resolution of about 0.1 degree. The eye-tracking device determines the positions of two elements of the eye, based on the centroids of pupil and the corneal reflection. This device has two sources of infrared light dilator, mounted at each lateral side of the lower monitor frame. The sensor is an infrared light sensitive video-camera, and the recording capabilities of this device are not interfered with room lighting. Analyses of recordings were computed using iView-software, SMI, BeGaze software and standard statistical softwares (i.e. Excel, SPSS, Statview). The experiments were presented on a 47 cm color, flat LCD monitor, and were monitored in a separate lap top where they were created.

Procedure

Experiment design. In order to provide a full counterbalancing, we randomly divided the total number of face pictures (80) into two separate “face conditions”. Thus, each face condition consisted of 40 pictures with equal numbers of pictures in respect of face gender and level of attractiveness (five male and five female pictures for each four level of attractiveness). Utilizing the same procedure, we created two “wine conditions” by randomly dividing the total number of wine images (40) into two equal groups. Therefore, each wine condition included 20 images (five pictures in each level of attractiveness). However, for wines, we tried to distribute pictures in such a way as to have an equal number of wine bottles in respective to the level of both design attractiveness and price. These four blocks (two wine conditions, two face conditions) were presented in a randomly assigned, counterbalanced, order between subjects. Participants took a short rest between conditions. The experimenter was not visible to the participants, though she was present in the same room.

Condition design. At the beginning of each condition, subjects read first an instruction explaining the calibration and validation procedures, where they were to follow (with their gaze) a calibration standard point (a red dot at the middle of a white circle presented in a grey background) that moved to 8 different positions on the screen. The experiment continued to the validation stage if the recorded eye positions had matched ideally with the calibration points. After these adjustments, a description of the task appeared on the screen which could be different depending on the type of condition. For the face condition, the instruction was: "Please imagine that you are the top manager of a Vinnmonopol store and you need to hire new personnel to work at the store. Please choose the level of salary (in NOK) that you would be willing to give to the persons you will see in this task." For the wine experiment, the task description was: "Please imagine that you are at the Vinnmonopol store in order to buy some wine. Please choose the price (in NOK) that you would be willing to pay for the bottles of wine you will see in the following trials." The descriptions were as follows: "In each trial, you will first see a fixation cross that you need to gaze upon, then you will be shown a picture, and in the last slide, you will be asked to answer the question. Please do not move your head while looking at the pictures." A practice trial, with a different image from the experimental pictures, was shown before presenting the main trials at the beginning of all four blocks of experiment.

Trial design. Each trial, in both face and wine experiments, consisted of presenting a pre-baseline slide for 5000 ms, a baseline, equiluminant fixation slide for 1000 ms, and a similar triggering fixation slide (staying on the screen until subjects had gazed on its fixation cross for 400 ms), respectively. Then, the main image of either face or wine bottle, depending on the type of experimental condition, was shown for 10000 ms. At the end of each trial, the questionnaire slide was presented for an unlimited time (Fig. 2). The question in the face condition was: "what monthly salary (in Kr) would you give to this person?" Under the question, there were four possible amounts based on the real salary basis in this market (taken from http://www.vinmonopolet.no), as follow: 26,000; 27,500; 29,000; and 30,500. For the wine, the question was: "How much (in Kr) would you pay for this wine bottle?" Under the question there were again four possible amounts based on the approximate range of wine prices in the market (taken from http://www.vinmonopolet.no), as follow: 1) 70-100, 2) 110-200, 3) 210-300, and 4) 300-450. However, subjects could choose only one answer between the offered amounts for each image, by the usage of a mouse. After making their decision, participants could continue to the next trial by clicking ‘continue’ by usage of a mouse, or pressing the [F11] key on the key board.

Personal questionnaire. After running all four experiments, each participant filled out a questionnaire probing their personal demographic information, along with the criteria that participants consciously used when making economic decisions. Their favorite brands of wine and/or the frequency of their wine consumption were also compiled (see Appendix 11). These data may help us to compare the obtained data from people with different value-criteria, drinking habits and attitudes towards drinks.

Data Analysis

Whole raw data. We had three general sets of data which consisted of: 1) E-prime output data files containing the ratings on attractiveness of faces and wine labels; 2) BeGaze output data files for: baseline and task-evoked pupillary responses, eye movements (number, duration and location of eye fixations on each picture and AOIs), and economic decisions; and 3) the data from a paper questionnaire regarding personal information which was entered manually into Statistical Package for the Social Sciences 18 (SPSS INC., Chicago, IL, USA).

Computing quartiles of attractiveness for faces and wine bottles. The average ratings on 114 female and 94 male pictures were computed using SPSS to obtain six total measurements as follows: Mean ratings of male and female perceivers on both male faces and female faces as well as mean ratings of whole participants on each face gender. The earlier measurements were used for probing gender differences in ratings on attractiveness, and the later one was used to sort pictures into four quartiles (see Appendix 1 & 2). The same procedure was done for attractiveness ratings on the images of wine bottles (see Appendix 4)

Raw pupillometric data. We used a repeated-measures (within-subject) design, so that each participant performed all conditions comprising the whole experiment. However, due to a technical error, the apparatus failed to record the pupillary data for five of the face pictures and for all participants. That is, our final pupillary data included 75 face pictures (instead of 80) as follows: 10 pictures of females (f) belonged to each of first and third quartile (q.1 & q.3) of attractiveness, and 10 male (m) pictures belonged to q.4. The rest of quartiles in each gender (i.e. f q2, f q4, m q1, m q2, m q3) included 9 pictures instead of 10. In contrast, we experienced no data loss regarding the 40 wine pictures. The pupillary changes in the left eye were used for analyses.

Processing of raw eye-tracking data. The raw eye tracking data were prepared by creating a JavaScript which sorted and organized the obtained raw data according to our main experimental factors for each experimental condition (face and wine bottle). These factors were as follow: gender of participant, gender of face picture, quartiles of attractiveness (for faces and wine bottles), quartiles of real wine price, type of wine labels (real or foil), handedness and direction of scrip reading (for laterality effects), and alcohol consumption.

Computing pupillary changes. Different standard statistical softwares (Excel, SPSS, Statview) were used in order to obtain the mean pupillary changes related to our different experimental factors (i.e. level of attractiveness of faces and\or wine labels, level of wine real price, gender of perceiver, gender of face, alcohol consumption, and type of label (real or foils). To do so, first, the average of pupillary changes during 10s presentation of each test image (either face or wine bottle), and during 1s presentation of its related baseline image (presented for 1s) were computed for each participant. Then, the difference between these two mean measurements was calculated (i.e. averaged pupillary changes during presentation of test image – averaged pupillary changes during presentation of baseline image) to obtain the pure mean pupillary response to each test picture for each participant. Finally, for each participant, the average of these subtracted pupillary changes was computed related to different categories (e.g. each participant's pupillary responses to each level of facial attractiveness for each sex). The average of pupillary changes during viewing each picture was also calculated across all participants. This was beneficial for later regression analysis between attractiveness ratings on each picture, and average pupillary responses to that.

Computing eye fixations data. The maximum number of fixations (MNF), along with the average of fixation durations (AFD) on each test picture (face \wine bottle), during 10s presentation, were computed for each participant. Finally, for each participant, the mean of MNF and AFD were calculated for each experimental factor. These averages were also provided for each picture across all participants for further regression analysis.

Areas of interest (AOIs). Twelve AOIs were defined for face stimuli as follows: Forehead, Hair, Jaw, Left-Cheek, Left-Eye and Eyebrow, Mouth, Nose, Right-Cheek, Right-Eye and Eyebrow, Left side of face, Right side of face (see Appendix 6). For wine bottles, six AOIs were defined as follows: Brand, Capsule, Graphics, Name of wine, Left side of bottle, Right side of wine bottle (see Appendix 7).

The same template was used to create these AOIs across all pictures of faces or wine bottles, but the precise sizes of each AOIs were adjusted manually for each picture. The average first fixation duration (AFFD), average number of fixations (ANF) and the average percentage time of total fixation duration (AFD) within each AOIs were sampled across participants along the main factors (see raw data processing for these factors). In SMI output files, the so-called percent fixation times are more precise than so-called percent dwell times, since the former measure does not include data recorded outside of fixations (Min duration, 80 ms; Max dispersion, 100 px), and percentage values have the advantage that they are independent of the absolute length of fixations.

The same standard statistical softwares (Excel, SPSS, Statview) were also applied in order to perform regression analysis, the repeated measures analyses of variance (ANOVA) and T-tests to examine our hypotheses.

Results

Facial Attractiveness

Behavioral Results

Gender-dependent effects in ratings on facial attractiveness. A repeated-measures ANOVA with ‘sex of participant’ as between-subjects factor and the ‘sex of face’ as within-subject factor revealed a main effect of sex of participants, F (1, 7980) = 19.071, $p < .0001$, and a main effect of sex of face, F (1, 7980) = 125.109, $p < .0001$ (Fig. 3). That is, female faces were rated more attractive than male faces, and female participants gave higher ratings on both female and male faces than male participants did. However, the interaction between sex of participant and sex of face failed to reach significance.

High agreement between women and men on facial attractiveness. A simple linear regression analysis showed a high correlation between the ratings of male and female participants on mean attractiveness ratings for each of the female faces, F (1, 102) = 444.98 $p < .0001$, r = .90; for male faces, F (1, 82) = 216.10, $p < .0001$, r = .85); and for all faces F (1, 186) = 696. 16, $p < .0001$, r = .88 (see Fig. 4).

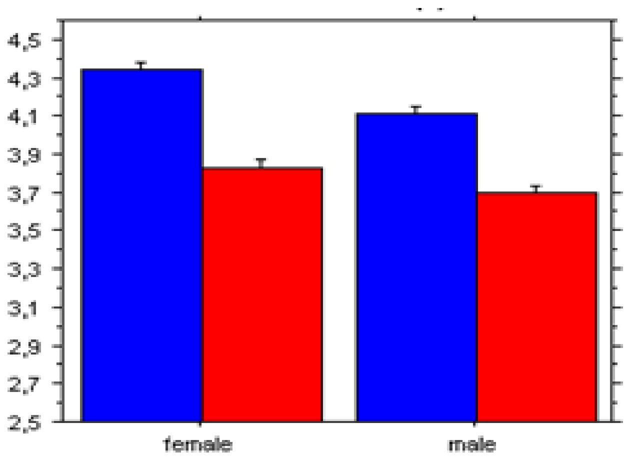

*Figure 3***.** Mean ratings on attractiveness; left columns belong to female faces; Blue column, female participants.

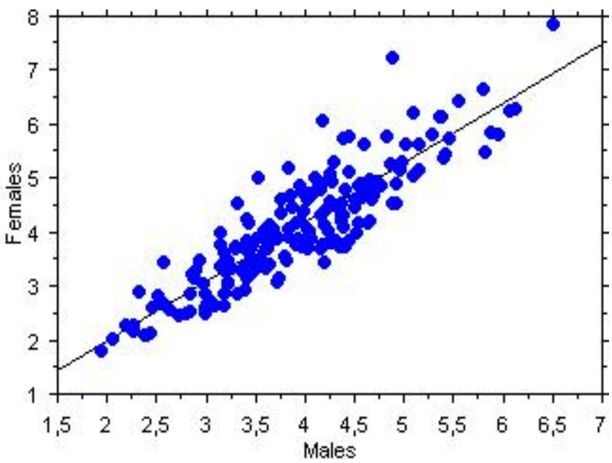

Figure 4. High correlation between ratings female and male percievers in attractiveness

Pupillometry Results

Pupillary changes can index level of attractiveness. A three-way repeated- measures ANOVA of pupillary change was performed with “quartile of attractiveness” and “sex of face” as within factors and “sex of participant” as between factor. Results revealed a main effect of attractiveness, F (3, 141) = 25.818, $p < .0001$, showing that, in accordance with our hypothesis, the pupil size increases as a function of level of facial attractiveness (see Fig. 5).

A further Sidak's multiple comparison analysis revealed that with the exception of no difference between first and second quartile of attractiveness, *(p* = 1.00), all other differences reached significance, (*p* < 001).

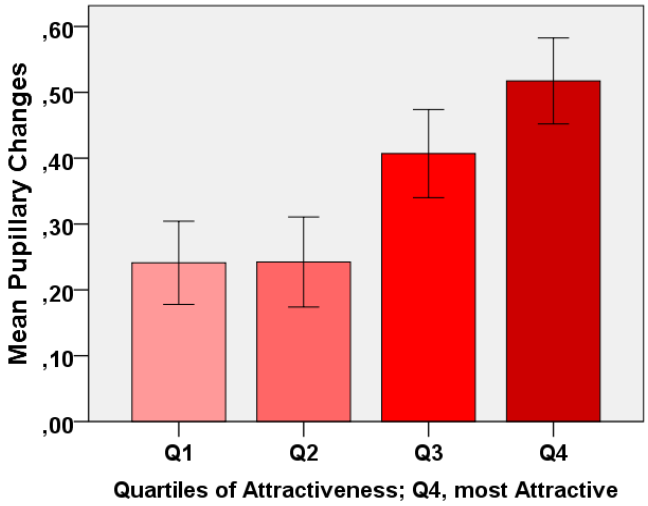

Figure 5. Pupillary dilations (in pixel) in response to facial attractiveness

Gender-dependent effects on pupil dilations. The three-way ANOVA also showed a significant interaction between "sex of face" and "sex of participant", F (1, 47) = 5.782, p = .02, indicating that larger pupil sizes in each sex were induced by faces of the opposite sex, irrespective of their level of attractiveness, which was consistent with our behavioral results (Fig. 6). This finding supports again our hypothesis about the effect of sex of face on pupillary dilations. However, paired sample t-tests revealed that female participants were the main cause of this interaction, by showing: 1) significantly larger pupil dilations in response to male faces than to female faces, t (1, 24) = -2.731, p = .012; and 2) significantly smaller pupil dilation in response to female faces, in comparison with male participants, t (1, 23) = 2.377, p = .02. In contrast, greater pupil dilations in men were irrespective of the sex of the face. The non- significant three-way interaction between sex of face, sex of participant and level of attractiveness, F (3, 141) = .422, p = .74, failed to confirm our hypothesis that the most attractive faces of the opposite sex induce the greatest pupillary dilations in the opposite-sex participants.

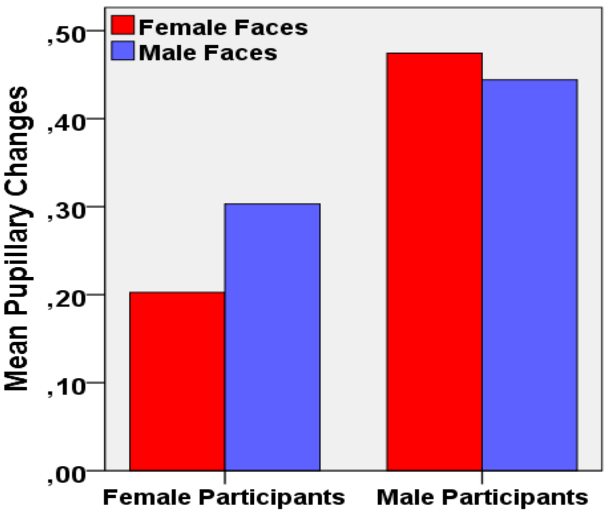

Figure 6. Gender-dependent effects of facial attractiveness on pupillary dilations (in pixel)

Finally, we found a significant interaction between sex of face and the level of attractiveness, F (3, 141) = 3.605, p = .015, indicating that only female faces with below median level of attractiveness (in second quartile) triggered significant smaller pupil dilations, t (1, 48) = -2.520, p = .015. There were no other significant results.

Eye Movements Results

Number of eye fixations can index level of attractiveness. A three-way repeated-measures ANOVA, with "sex of face" and "quartile of attractiveness" as within-subjects factors, and "sex of participant" as a between-subject factor, revealed a main effect of quartiles of attractiveness, F (3, 141) = 5.696, $p < .001$ (Fig.7), which supports our hypothesis and holistic perception of facial attractiveness. Sample t-tests showed that the number of fixations decreased when the level of attractiveness increased from first to second quartile, t (1, 48) = 3.93, $p < .000$, and then further increased when the level of attractiveness went above the median level of attractiveness, t (1, 48) = -2.397, p = .02 (between quartile two and three). In spite of that, significant smaller number of fixations between first and fourth quartile, t (1, 48) = 2.138, p = .038 showed that a higher level of attractiveness causes gaze to move less or, in other words, to "freeze" into a stare.

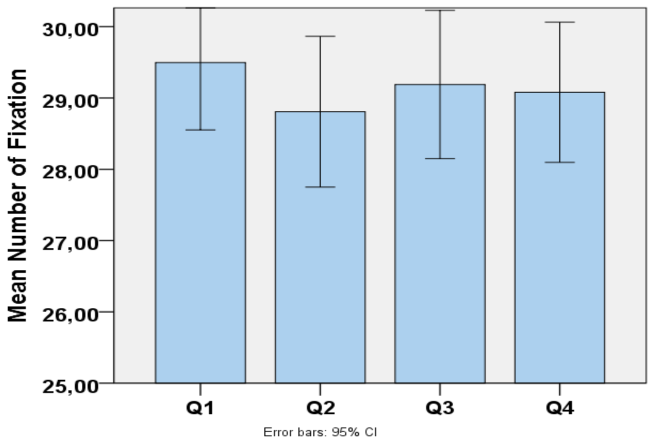

Figure 7. Number of eye fixations in response to facial attractiveness; Q4, most attractive faces

Gender-dependent effects of facial attractiveness on number of eye fixations. Similarly to pupillary responses, a repeated-measures ANOVA revealed a significant interaction between sex of face and sex of participant F (1, 47) = 8.90, p = .05 (Fig. 8). Further analyses indicated that women, in comparison with men, searched for more information and generated marginally greater number of fixations while looking at faces (p = .07), and significantly more at female faces, t (1, 48) = -2.36, p = .023. In contrast, men made a greater number of fixations on male than female faces, t (1, 23) = -3.85, p = .001, which again shows a reduced movement of gaze when looking at female faces.

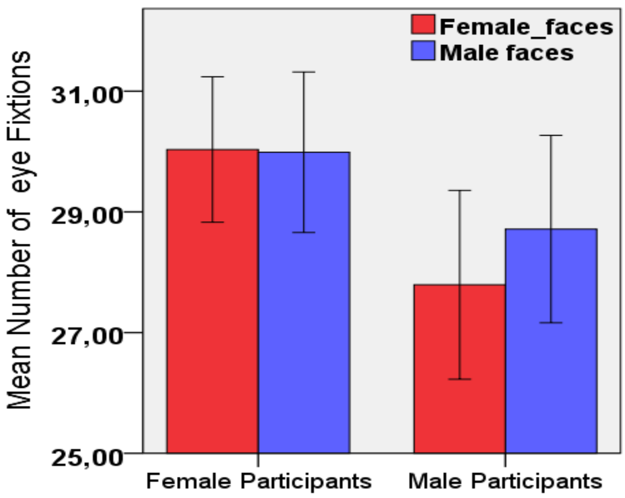

Figure 8. Gender-dependent effects of facial attractiveness on number of fixations

Another significant gender-related interaction was between sex of face and quartile of attractiveness, F (3, 141) = 6.037, p = .01, generally suggesting that for male faces, in contrast to female faces, when the level of attractiveness increases, the number of fixation decreases (Fig. 9)

Finally, the analysis also showed a main effect of sex of face, F (1, 47) = 8.06, $p < .007$, indicating that male faces triggered greater number of eye fixations than female faces, t (1, 48) = -2.43, p = .019.

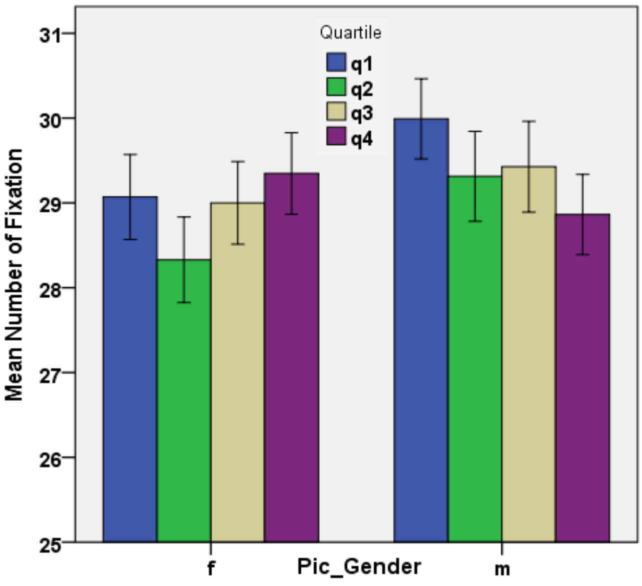

Figure 9. Interaction between quartiles of attractiveness and gender of faces for number of fixations; f, Female faces; q4, most attractive faces

Results of Economic Decisions

Level of attractiveness, sex of participant, and sex of face all affect the level of offered salary. A three-way repeated-measures ANOVA, with “sex of face” and “quartile of attractiveness” as within-subject factors, and “sex of participant” as a between-subjects factor, revealed a three-way interaction between these factors, F (3, 141) = 3,21, p = .025, as well as a main effect of quartiles of attractiveness, F (3, 141) = 42.55, p = .000, (Fig. 10). Therefore, results confirmed our hypothesis that level of attractiveness can predict a parametric increase in the estimated salaries, particularly to the most attractive faces of the opposite-sex.

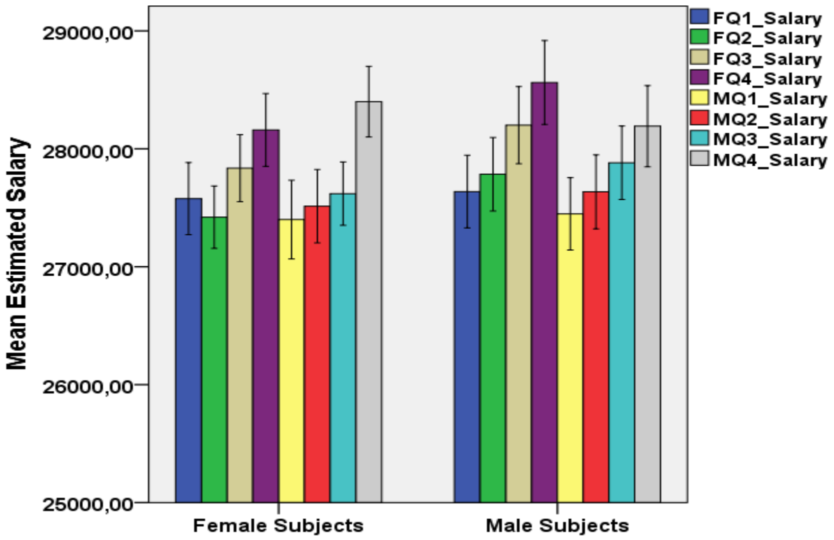

Figure 10. Three-way interaction between level of attractiveness, sex of face and estimated salaries; F, Female faces; Q, quartile of attractiveness

A Sidak’s multiple comparison analysis indicated that, with the exception of no difference between 1st and 2nd quartile (p = .75), all other differences between quartiles were significant, $p < .000$. No other significant result was found.

Regression Analyses

Moderate linear correlation between pupillary dilations and absolute ratings of attractiveness. A simple linear regression analysis revealed a linear increase in pupil size as a function of increase in ratings on facial attractiveness, F (1, 73) = 4.938, p = .029, r = .25, indicating the continuum nature of pupillary reactions. This correlation should also be seen in the light of the fact that the pupillary responses and ratings on attractiveness were taken from two different groups of participants. We also found a marginally significant correlation between estimated salaries and pupillary dilations F (1, 73) = 3.449, p = .067, r = .21.

High linear correlation between estimated salary and absolute ratings on facial attractiveness. As predicted, a significant linear increase in offered salaries was observed when faces were rated as more attractive, F (1, 75) = 53.853, p < .0001, r = .65. (Fig.11).

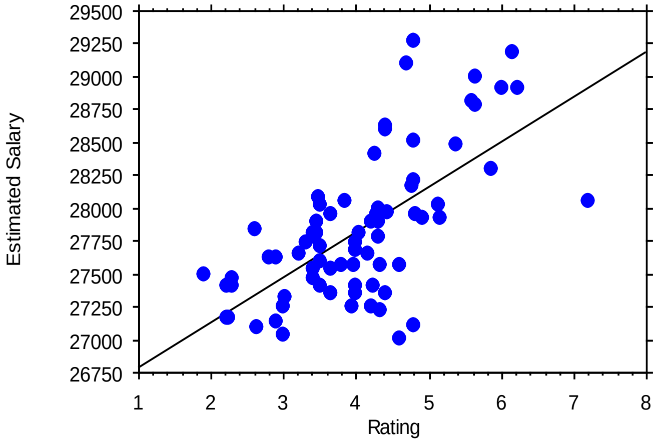

Figure 11. High correlation between absolute ratings on facial attractiveness and offered salaries

Areas of Interests (AOI) Analysis

Fixation Duration

Percent time of eye fixations differs for the various areas of the face (see Appenix 6b & 8). A four-way repeated-measures ANOVA, with "sex of participant" as between-subjects factor and "sex of face", "AOIs" (nine areas), and "level of attractiveness" as within-subject factors, revealed a main effect of AOIs, F (8, 376) = 268.4, p < .0001, (Fig.12), indicating that eyes (either left or right), nose, and mouth, respectively, are the most often observed areas in the faces, as it was expected (Sidak's p < .000, but

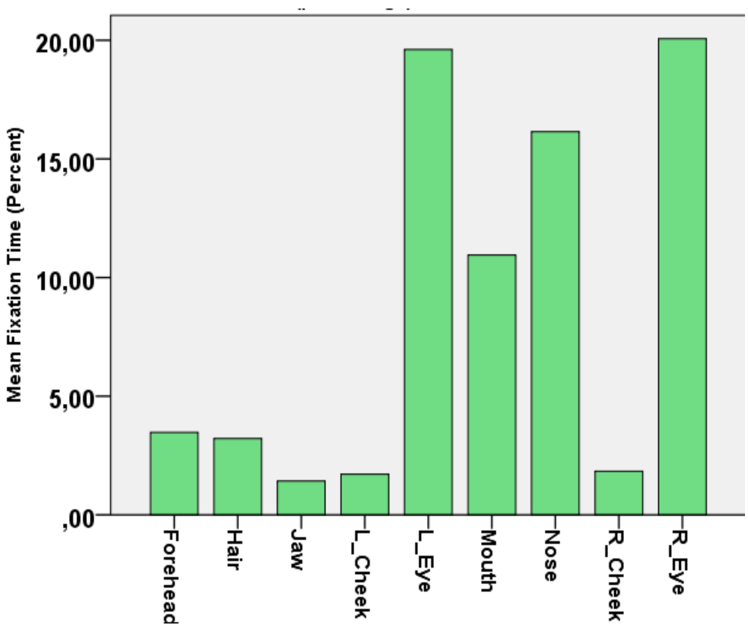

Figure 12. Results from AOIs analysis showed that the eyes, nose and mouth triggered the longest eye fixations (percent time), respectively.

difference between eyes and nose $p = .05$). However, Sidaks' multiple comparison analysis showed no difference between left and right eye, $p = 1.0$. Based on these findings, for further analysis, the data of two eyes were merged together and was used, since it appeared to be the most influencial feature in faces (see Appendix 8 for an illustration of resulu for each AOIs).

In addition, ANOVA's results showed a main effect of attractiveness , F (3, 141) = 3.94, $p = .009$, and a significant interaction between AOIs and of attractiveness, F (24, 1128) = 3.14, $p < .0001$. This relative increase in fixation duration during viewing more attractive faces is consistent with our previous results on number of fixations, showing that viewing more beautiful faces is accompanied with fewer number of fixations.

Gender- dependent influences in AOIs' analysis. A significant interaction between sex of face and level of attractiveness was found, F (3, 141) = 7.57, $p < .0001$, (Fig. 13), and post hoc analysis showed that in general female faces triggered the longest fixation times (however, the difference between female faces in Q2 and Q4 failed to reach significance. , $p = .66$).

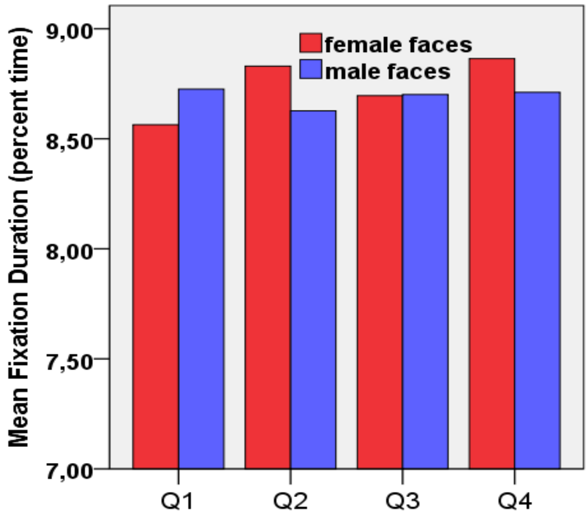

Figure13. Female faces triggered longer fixations (in Q2 & Q4); Q, quartile of facial attractiveness

Results from ANOVA also showed that the mean duration of eye fixations on different areas of face are influenced by three factors: sex of face, the level of attractiveness , and parts of face, which interact with each other, F (24, 1128) = 4.77, $p < .0001$ (see Appendix 10). Further, Sidak's multiple comparison analysis on the eyes in female faces confirmed that when the level of attractiveness increases, the duration ofeye fixations on the eyes increases as well, $p_{q1\ \&\ q4} < .0001$ (Table 1), but this is not the case for male faces. Moreover, we observed a three-way interaction between sex of face, sex of participants, and AOIs, F (8, 376) = 3.91, $p < .0002$.

Quartiles of Attractiveness	Mean	SD Error	95% Confidence Interval	
			Lower Bound	Upper Bound
Q1	19,609	,683	18,235	20,982
Q2	20,509	,712	19,077	21,941
Q3	20,601	,730	19,134	22,068
Q4	21,366	,785	19,788	22,945

Table 1. Mean fixation durations (pecent time) on the females' eye for four quartiles of attractiveness

Further analysis on the eyes indicated that when the level of attractiveness in female faces increased, the eyes triggered significantly longer eye fixations, but only in male participants *p (q1 & q3)* = .03; *p (q1 & q4)* = .005 (Fig. 14). In additions, men generated longer fixations on female faces than male faces (Fig. 14).

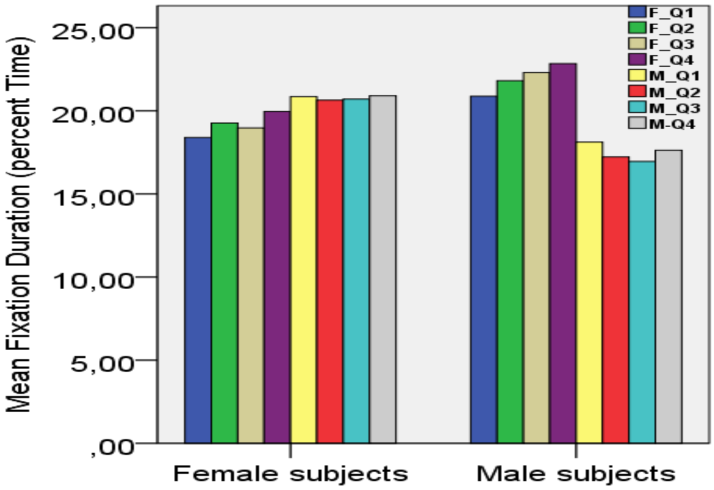

Figure14. Average fixation durations in male and female participants on the eyes of male and female faces with different level of attractiveness, F, females; Q, quartiles of attractiveness

Laterality Bias toward Faces

Effect of first-language and handedness on biasing visual search toward the left side of faces. A four-way ANOVA analysis with the whole data , and "sex of participant" as between-subjcets factor and "side of face", "level of attractiveness" and "sex of face" as within-subject factors showed just a marginal effect of side of face, , F (1, 47) = 3.25, p = .07 (Fig.15).

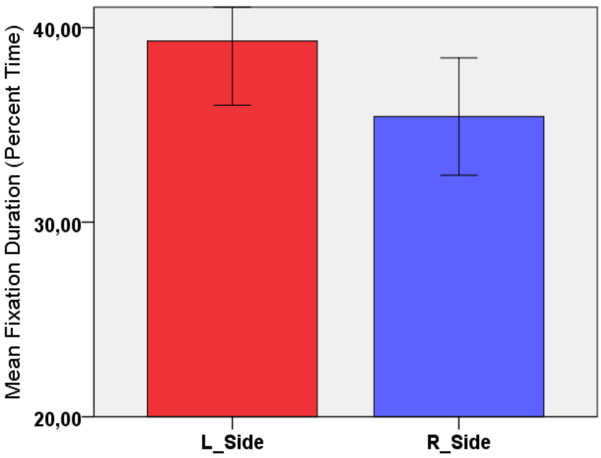

Figure15. Average fixation time in left versus right side of faces

However, based on previous findings on the effects of the direction of writing of participants' first language, and their handness on emerging left side bias, the data taken from left-hand participants (N=5) and those whose first written languages were from right to left (e.g. persian and arabian languages, N=10) were excluded. Two four-way repeated-measures ANOVAs were performed with the same factors, one included the left-hand particpants (N=39, Females= 20), and in the other one these participants were excluded (N=34, Females=17). Results from first group revealed a significant interaction between sex of face, level of attractiveness, and side of face, F (1, 37) = 3.99, p = .01. A similar interaction was found with the second group F (1, 32) = 3.72, p = .014, suggesting that when level of attractiveness increases, the left side of female faces triggers significant longer eye fixations *t (lq2& lq3)* (1, 33) = -6.97, p < .000 (Fig. 16). However, the difference between left and right side in Q4 (i.e., the most attractive) of male faces also reached marginally significance, p = .058.

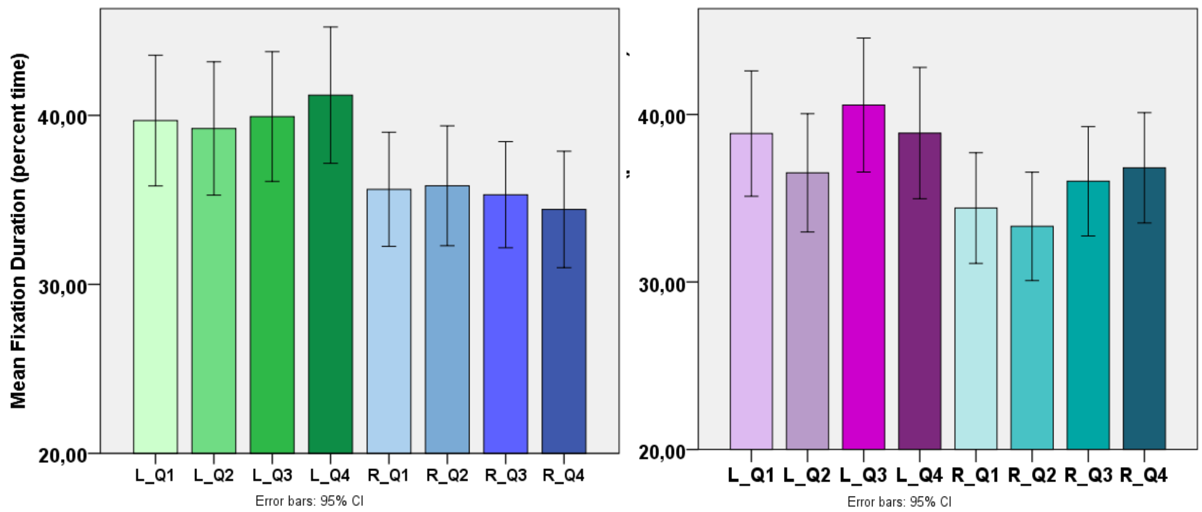

Figure16. Mean eye fixation duration (percent time) on left and right side of male (left side) and female (right side) faces in each quatile of attractiveness. L= left side of face, R= right side of face, Q= quartile of attractiveness

Attractiveness of Wine Labels

Behavioral Results

There were no gender differences in ratings of attractiveness of wine labels. A repeated-measures ANOVA with "sex of participant" as between-subjects factor and "type of label" ('real label', used in the market, versus 'foil labels', not used in the market) as within-subject factor revealed that neither sex of rater, F (1, 38) = .841, *p* = .36, nor type of label, F (1, 38) = .013, *p* = .91, had significant effect on ratings on wine labels' attractiveness.

High agreement between women and men on attractiveness of wine labels. As with the face data, a simple linear regression analysis showed a high correlation between the ratings of male and female participants on the attractiveness of wine labels, *F* (1, 38) = 22.96, *p* < .0001, r = .61, (Fig. 17).

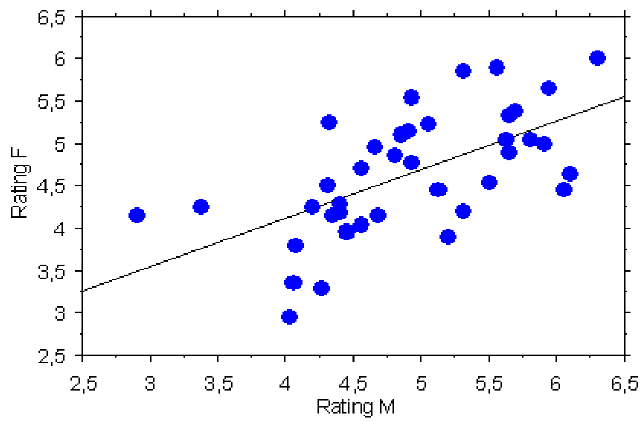

Figure17. correlation between male and female ratings on attractiveness of wine

Pupillometry Results

U-shape pupillary dilations in responses to the level of attractiveness of wine labels. A two-way repeated-measures ANOVA of pupillary responses was performed with "quartiles of labels' attractiveness" as within-subject factor and "sex of participant" as between-subjects factor. In accordance with our hypothesis, a main effect of level of attractiveness was significant, *F* (3, 141) = 25.98, $p < .0001$ (Fig. 18). However, differently from the analysis with faces the level of attractiveness of wine labels (as a non-social stimulus) appeared to have a U-shape effect on pupillary dilations. All means were significantly different, $p < .0001$, except the 1st versus 4th quartile, $p = .433$, and the 2nd versus 3rd quartile, $p = .52$.

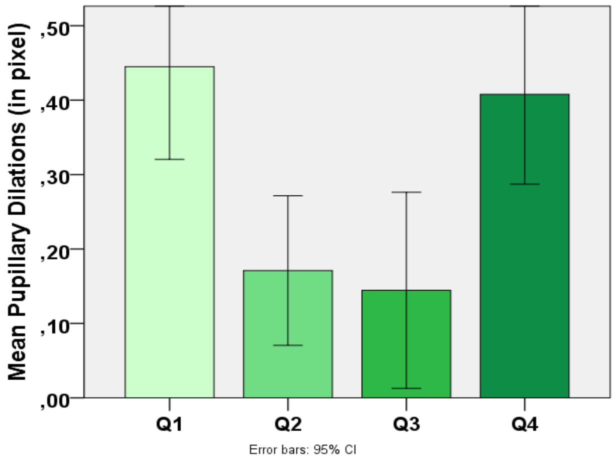

Figure 18. Average pupillary dilations in response to level of attractiveness in wine labels; Q, quartile of attractiveness

Moreover, consistently with our behavioral results, there was no significant difference in pupillary dilations between men and women ($p = .25$). Likewise, we did not find significant difference between alcohol consumers and non-consumers (N=12), *F* (1, 47) = 1.08, $p = .305$.

Pupillary dilations can index the level of real (market) price of wine bottles. Another two-way ANOVA analysis, with "quartile of real prices" as within-subject factor and "sex of participant" as between-subjects factor, revealed a main effect of level of price, *F* (3, 141) = 3.09, $p = .03$, (Fig. 19) indicating a significant difference between 1st and 3rd quartiles ($p = .02$), and a marginal significant difference between 2nd and 3rd quartiles ($p = .06$). These different patterns of pupillary responses to the level of attractiveness and price suggest that apparently only the most unattractive (i.e., aversive) and the most attractive (i.e., rewarding) labels induce arousal and in turn they provoke larger pupillary dilations. However, when it comes to market price, the more expensive a wine is larger the pupil dilations will be, indicating that wine labels per se are capable of conveying price information and its associated rewarding value. There was no other significant difference, nor between women and men (*F* (1, 47) = 1.46, $p = .23$), neither between alcohol consumers and non-consumers (*F* (1, 47) = 1.73, $p = .19$).

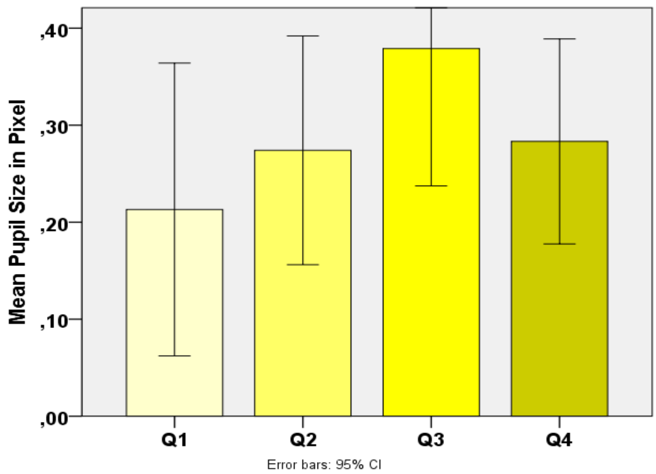

Figure 19. Average pupillary dilations in response to real price level (market price) of wine bottles; Q, quartile of wine real price

Increased pupil size in response to real labels in comparison to foil labels. Interestingly, a three-way repeated-measures ANOVA with "type of label" as within-subject factor, and "alcohol consumption" and "sex of participant" as between-subjects factors revealed a main effect of type of label, F (1, 45) = 4.56, p = .038, indicating that real wine labels induced significant bigger pupil sizes in comparison with those which were discarded from market (Fig. 20).

More interestingly, there was a significant interaction between type of label and consumption of alcohol, F (1, 45) = 5.62, p = .02, clarifying that real labels induce larger pupil size only in alcohol drinkers, t (1, 37) = -4.56, p <.000).

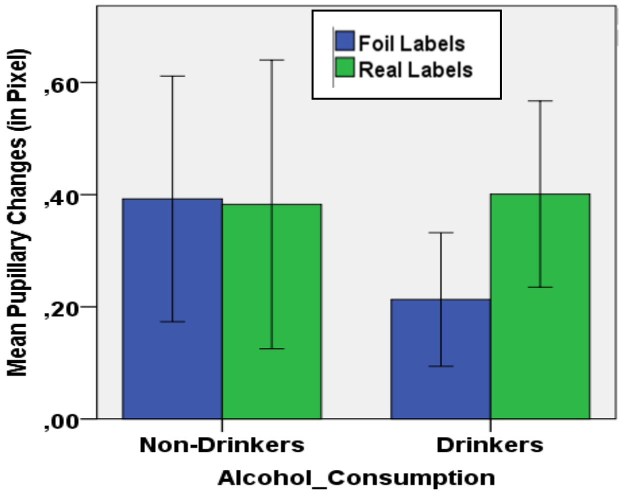

Figure 20. The pupils of Alcohol drinkers dilated larger in response to real labels (market labels) than foil labels, in comparison to non-drinkers

Eye Movements Reasults

Wine labels with Above the median level of attractiveness trigger a greater number of eye fixations. A two-way repeated-measures ANOVA, with "quartile of attractiveness" as within-subject factor, and "sex of participant" as between-subjects factor, revealed a main effect of level of attractiveness, F (3, 141) = 3.89, p = .01 (Fig. 21). The differences between Q1 and Q2 (p=.006), and between Q2 and Q3 (p < .001) were significant (between Q2 and Q4, p = .07). In order to achieve a better understanding of these effects, the data were split above and below the median levels of attractiveness. A paired sample t-test showed a significant greater number of fixations when viewing labels over median level of attractiveness t (1, 48) = -2.08, p = .04.

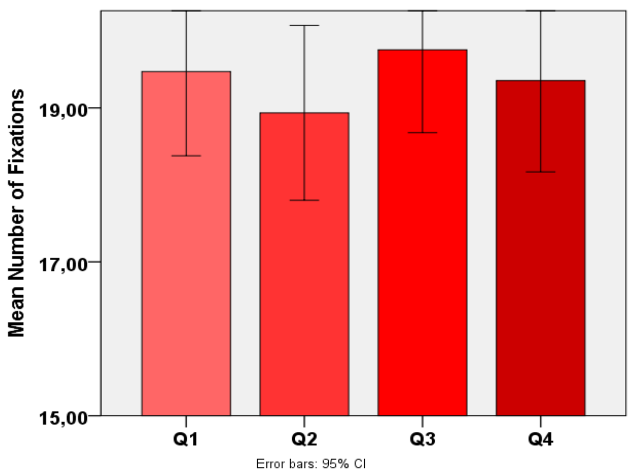

Figure 21. Mean number of eye fixations during observing wine labels with different level of attractiveness; Q, quartiles of attractiveness

Gender differences in number of eye fixations. Similar to the faces' results, women generated a marginally greater number of fixations than men, F (1, 47) = 3.9, p = .054.

Level of price did not influence number of eye fixations. A similar two-way repeated-measures s of ANOVA did not show any effect of price level on the number of eye fixations, *F* (3, 141) = 1.81, *p* = .148. No gender differences were found either, *F* (1, 47) = .37, *p* = .07.

Real labels triggered a greater number of eye fixations than foils. A three-way repeated-measures of ANOVA with "type of label" as within-subject factor and "sex of participant" and "alcohol consumption" as between-subjects factors revealed a main effect of type of label *F* (1, 45) = 24.45, *p* < .000 (Fig.22). A similar two-way ANOVA with "sex of participant" as between-subject factor showed significant higher number of fixations in female participants, *F* (1, 47) = 4.05, *p* = .05 (Fig.22).

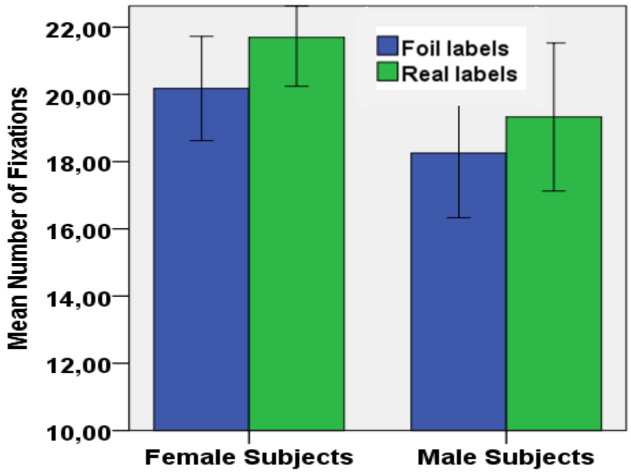

Figure 22. Females generated greater number of fixations during viewing real (in market) labels

Alcohol consumption did not influence the number of eye fixations, neither in response to the level of attractiveness, *F* (1, 47) = .37, *p* = .55, nor in response to the level of real price of wine, *F* (1, 47) = .22, *p* = .64, nor to the type of label *F* (1, 47) = .49, *p* = .49.

Results of Economic Decisions

The more attractive a wine label looks, the more money people will pay for the wine. As explained in method section, participants could choose between one of four ranges of prices to express how much they were willing to pay for each wine. A two-way repeated-measures ANOVA was performed, with "quartile of attractiveness" as within-subject factor, and "sex of participant" as between-subjects factor and "mean level of estimated price", (given to each quartile of attractiveness) as the dependent variable. Results showed a main effect of level of attractiveness, *F* (3, 141) = 44.34, *p* < .000 (Fig.23), indicating a linear increase in level of estimated price as the level of attractiveness increased

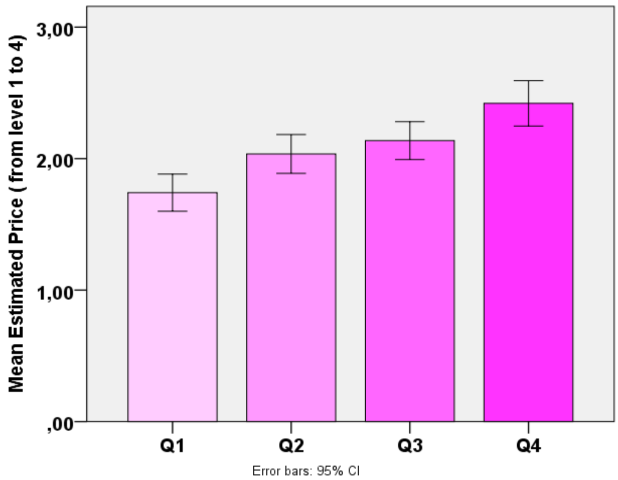

Figure 23. Average offered prices for each quartile of attractiveness in wine labels; Q, quartile of attractiveness in labels

(all differences are significant, Sidak's $p < .000$). There was no other significant result.

People are willing to pay more for the more expensive wines (in the market). A two-way ANOVA was performed with "quartile of real price of wine bottles" as within-subject factor. Results revealed a main effect of price level, F (3, 141) = 21.51, $p < .000$ (Fig.24). The difference between 1st and 3rd quartile failed to reach significance, Sidak's $p = .19$. A later assessment showed that wine labels in the third quartile of price (i.e. expensive wines), had been rated as having the least attractive labels (first quartile of attractiveness). This may explain why participants offered low prices for these relative expensive wines (Fig.24). No other significant result was found.

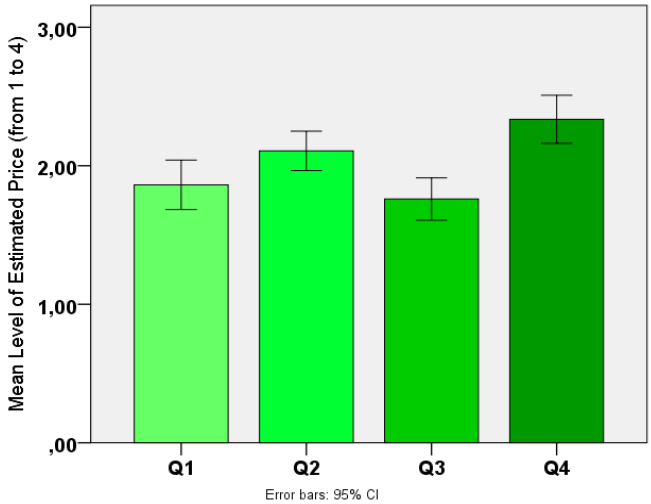

Figure 24. Average offered prices for wine bottles belonged to each quartile of real (market) price; Q, quartile of real price

There was no significant difference between estimated prices for the real labels and foil labels F (1, 47) = .26, $p = .61$. In addition, ANOVA analysis with "alcohol consumption" as a between-subjects factor did show neither a significant difference between alcohol drinkers and non-drinkers in their price estimations for each level of labels' attractiveness F (1, 47) = .001, $p = .875$, nor to each level of real price of wine labels, F (1, 47) = .05, $p = .83$, or to different types of label (real and foil), F (1, 47) = .008, $p = .93$.

Regression Analysis

High correlation between absolute ratings on attractiveness of wine labels and the estimated prices by another group of participants. A simple linear regression analysis revealed a linear increase in ratings of attractiveness of labels increase offered prices by participants as the, F (1, 38) = 84.22, $p < .0001$, r = .83 (Fig.25). Moreover, a positive correlation between the real prices of wine bottles and

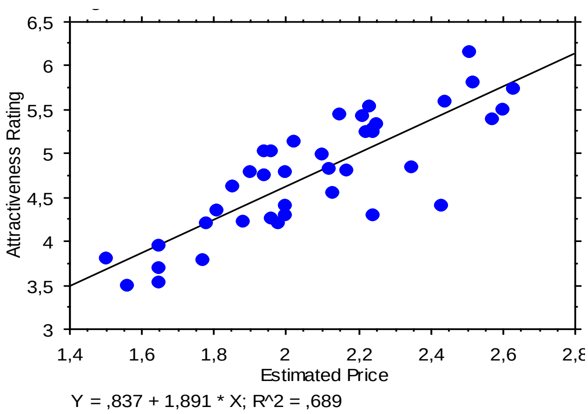

Figure 25. correlation between ratings on attractiveness of wine labels (Y axial) and level of estimated price (x axial)

estimated prices by participants was found, $F(1, 38) = 6.95$, $p = .01$, r = .39.

Areas of interests (AOI) analysis

Fixation Duration

The effect of attractiveness of label on visual behavior depends on the areas of the wine label we look at (see Appendix 7b & 9). A three-way repeated-measures ANOVA, with "alcohol consumption" as between-subjects factor and "level of attractiveness", and "AOIs" (four areas: Brand, Name, Graphics, and Capsule) as within-subject factors, revealed a main effect of attractiveness, $F(3, 141) = 52.37$, $p < .0001$, indicating a significant decrease in duration of fixations when the level of attractiveness increased. All differences were significant (Sidak's $p < .000$) except between quartile one and two ($p = .53$). The difference between quartile two and three is also marginally significant, $p = .054$.

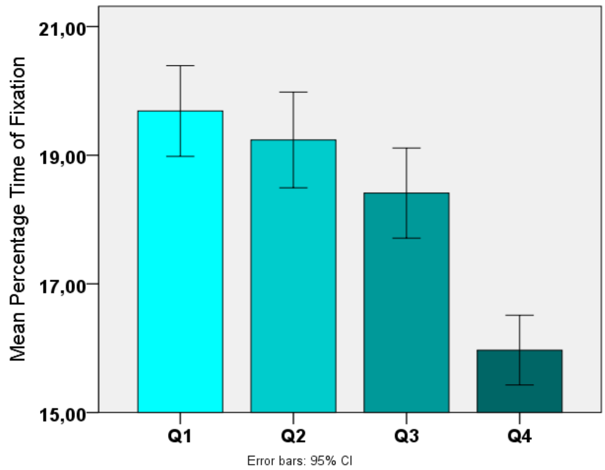

Figure 26. Average fixation durations decreased when the level of attractiveness in label increased.

Results from ANOVA showed also a main effect of AOIs, $F(3,141) = 290.81$, $p < .0001$ (Table.2), indicating longer fixations on graphics, wine name, brand and capsule, respectively (Sidak's $p < .000$, but between graphics and name, $p = .004$).

Descriptive Statistics

	Mean	Std. Deviation	N
Brand	12,2009	3,13996	49
Capsule	4,6599	2,02234	49
Graphics	30,2374	3,84969	49
Name	26,2465	6,20180	49

Table 2. Mean fixation duration (percent time) on each AOIs of wine labels

Finally, there was a significant interaction between AOIs and level of attractiveness, $F(9, 423) = 15.18$, $p < .0001$, indicating that when levels of attractiveness increased, participants looked longer at the brand compared to graphics and wine name (Fig. 27). The differences between 3rd quartile and three

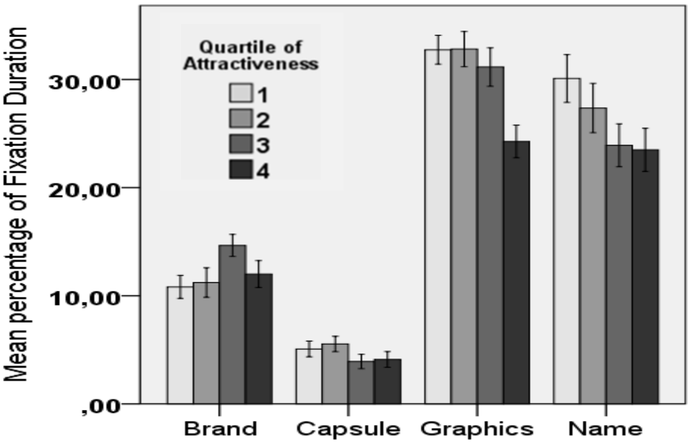

Figure 27. Average fixation duration in each AOIs and quartile of attractiveness

other quartiles of brand are significant (Sidak's $p < .000$). Likewise, the differences between 4th quartile and three other quartiles of graphics were significant (Sidak's $p < .000$). The differences between all quartiles of wine name were also significant, exception of that between quartile three and four, Sidak's $p = .99$ (see Appendix 9 for an illustration of results).

The more expensive a wine is (in the real market) the longer one looks at the graphics and wine name. A two-way repeated-measures ANOVA with "AOIs" and "levels of real price of wine bottles" as between-subjects factors revealed a significant main effect of price, $F(3,144) = 87.53$, $p < .0001$, indicating general increase in percentage time of fixations as level of price increases. All differences were significant (Sidak's $p < .000$), exception of between 2nd & 4th Sidak's $p = .07$) (Fig. 28).

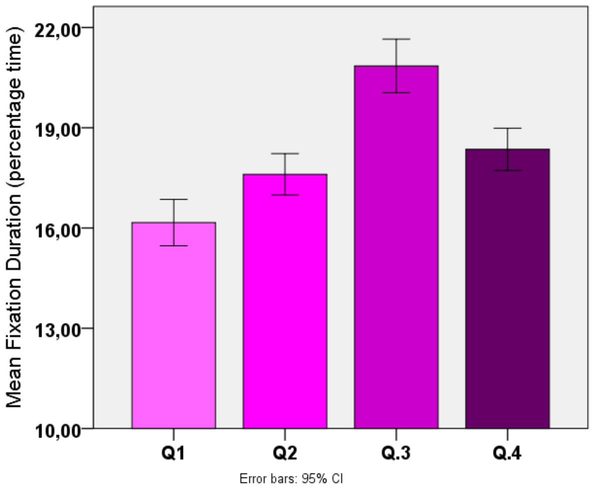

Figure.28. Average fixation durations increased when the real price levels (in market) increased

Results from ANOVA also showed a significant main effect of AOIs, $F(3,144) = 354.72$, $p < .0001$, indicating again that participants looked longer at graphics, wine name, brand and capsule, respectively. However, the difference between graphic and name failed to reach significance (Sidak's $p = .58$).

Finally, a significant interaction was found between level of real price and AOIs, $F(9, 432) = 73.69$, $p < .0001$ (Fig. 29). As shown, when the levels of price increases, then the graphics and wine name are viewed for a longer duration, in contrast to the effect of level of attractiveness which caused participants to attend to brand for longer time with higher attractiveness (see above). All differences between quartiles of graphics are significant (Sidak's $p < .000$), except between 2nd and 4th quartiles (Sidak's $p = .87$). For the wine names, differences between Q1 and Q3, Q2 and Q3, Q2 and Q4 (Sidak's $p < .000$), and Q3 and Q4 ($p = .012$) are significant. All differences between quartiles of brand are also significant (Sidak's $p < .000$, except between Q3 & Q4, $p = .051$).

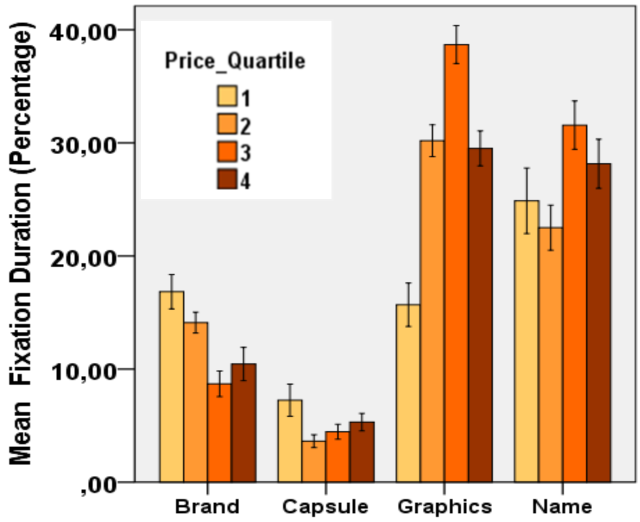

Figure 29. Average fixation time in each quartile of real (market) price and each AOIs

Graphics of real labels are more eye-catching than graphics of foil labels. A two-way repeated-measures ANOVA with "AOIs" and "type of label" as within-subject factors revealed a main effect of AOIs, F (3, 141) = 476.5, $p < .0001$, and a significant interaction between type of label and AOIs, F (3, 141) = 15.27, $p < .0001$, indicating significant longer fixations on the graphics of the real labels than that of foil labels, Sidak's $p < .000$ (Fig. 30).

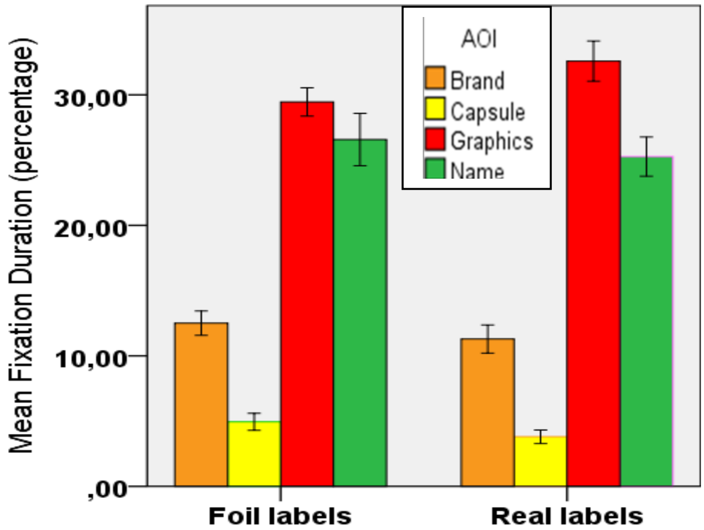

Figure 30. Average fixation time on each AOIs of wine labels

In general, there was no significant difference between females and males in the duration of eye fixations on different areas of wine bottles, F (1, 47) = .66, p = .42, nor between alcohol drinkers and non-drinkers F (1, 47) = .28, p = .59. However, further analysis showed that there was only one marginal significant difference between alcohol drinkers and non-drinkers related to the real and foil labels, showing longer eye fixations on the graphics of real labels in the former than the latter group (Sidak's p = .07).

Laterality bias in processing wine bottles

The left side of wine bottles triggers a greater number of eye fixations and longer gaze. As for faces, we investigated if there is a left bias in visual behavior during observing wine bottles as objects. Two two-way repeated-measures ANOVA were performed with side of bottles (left & right) and quartile of attractiveness as between-subjects factors, and either the mean duration of fixations or mean number of fixations as dependent variables. Results revealed a main effect of side of bottles, F (1, 48) = 12.98, $p < .001$, indicating longer fixations on the left side of bottles (Fig. 31). Moreover, there was a main effect of level of attractiveness, F (3, 144) = 8.32, $p < .000$, indicating longer fixations when

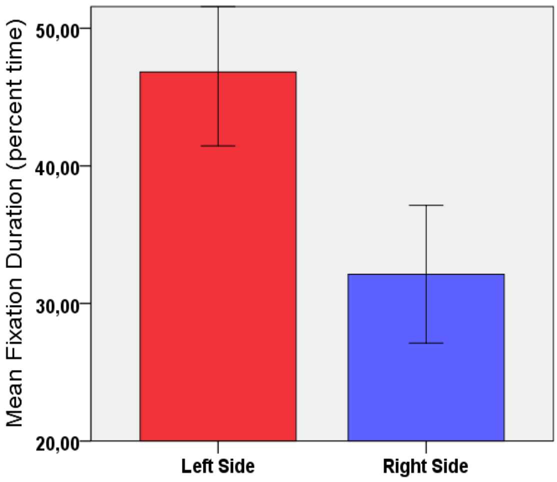

Figure. 31. Left side bias during screening wine bottles

attractiveness increases (Sidak's p (q1 &q3) $< .000$, p (q1 &q4) $= .04$, p (q2 &q3) $= .03$).

The second ANOVA revealed also a main effect of side, $F(1, 48) = 14.26$, $p < .000$ (Fig. 32), indicating greater number of eye fixations on the left side of bottles (Sidak's $p < .000$), and a main effect of level of attractiveness, $F(3, 144) = 4.92$, $p < .003$, indicating that more attractive labels induced greater number of eye fixations (Sidak's p (q1 &q3) $< .035$; p (q2 &q3) $< .031$).

These significant effects were found even when all data taken from all participants were included in analysis, without requiring participants or those whose written languages were from right to left. However, when these were excluded, an interaction between side of bottle and level of attractiveness was also found for fixation durations, $F(3, 99) = 3.28$, $p < .09$.

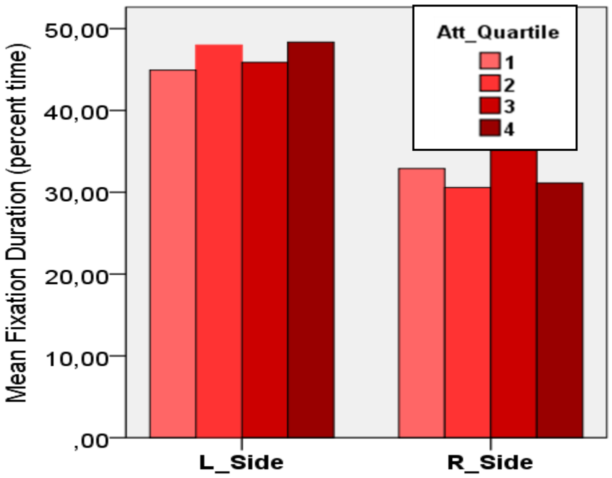

Figure 32. Effect of label attractiveness on average fixation time toward left side

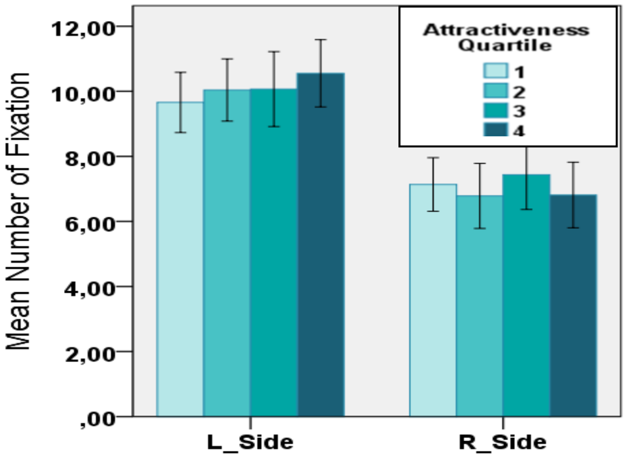

Figure 33. Effect of label attractiveness on average number of eye fixations toward left side

Demographic data taken from final questionnaire

The average age of participants in the main eye-tracking study was 25.57 (SD, 6.13), of 49 participants 25 were females, 29 from Norway, 29 atheists (11, Christians; 9, Muslims), 37 alcohol drinkers, and 44 right-hands. Eighty percent of participants were either a little familiar (N=20) or moderately familiar (N=24) with the salary system in Norway. The majority (N=42) never had hired any personnel before, their monthly income was either under 10,000 Kr (N=28), or between 10,000-20,000 Kr (N=16), and did not use to pay more than 110-200 Kr for a wine bottle. Moreover, 42 subjects mentioned that both sexes are suitable for working at a wine store, and 32 considered themselves as either naive or ignorant in wine knowledge. Italian, Spanish and French wines were respectively the most preferred wine brands between our subjects. The majority of alcohol drinkers reported preferring either wine (N=18) or beer (N=14), and of 37 alcohol consumers, 24 preferred red wines (N=24) over other types of wine. Likewise, the majority (N=29) reported drinking wine only in social occasions (at meal time, N=2). About frequency of drinking wine, seventy percent of participants claimed they drink wine only couple of times per month (N=20) or just on the weekends (N=15), and only one of alcohol drinkers reported that he does not drink wine.

More interestingly, 30 participants mentioned facial attractiveness as one of their four criteria to make economic decisions for salaries. Their impression of faces' Capability (N=30), Age (N=28), Trustworthy (N=24), Friendliness (N=23), and Experience (N=20) were between other four criteria that participants reported as their considerations in order to choose the salary, though faces were neutral (see Appendix 11).

For wine bottles, almost all participants (43) determined the design of label to be one of their four criteria in their economic decisions. Their level of Income (N=21), wine name (N= 12), their Familiarity with the brand (N=11), and Year of production (N= 9) were between other reported four criteria in order to choose the prices they would be willing to pay for each wine bottle (see Appendix 11).

Discussion

This study had four main purposes. Namely, we aimed 1) To investigate whether pupillary responses and eye movements can index different levels of attractiveness or hedonic value for both social and non-social stimuli (faces and wine labels, respectively). 2) To observe whether the attractiveness or hedonic value (of either faces or labels) has measurable and common effects (across stimulus type) on subsequent economic decisions. 3) To identify which visual features in faces or labels contribute to reward evaluations and subsequent economic decisions. 4) To discover and/or confirm the presence of gender differences in hedonic responses to faces and wine labels.

In general, we were able to provide significant evidence for all of our experimental goals, by applying precise procedures and carefully selected stimuli.

In practice, we presented photos of faces of both sexes as well as photos of bottles of Italian wines to a group of participants, and asked them to make an economic decision and determine the salaries or the prices they would be willing to assign respectively to each of the faces and wine bottles. In this way, we could investigate how visual attributes can determine economic value. Both the pictures of the faces and those of the wines had been previously rated by a group of participants for their attractiveness or aesthetic/hedonic value. Simultaneously to these judgments, we measured the eyes' positions as well as changes in diameter of the eye pupil by use of an infrared eye-tracker. These psycho-physiological measurements can provide an index of the change in attention allocation relative to the previously rated aesthetic value and relative to the current estimated economic values.

Pupillary findings

A parametric increase in pupillary dilations in response to over-the-median levels of facial attractiveness confirmed our hypothesis. In the present study the effects of luminance was controlled precisely, the stimuli were presented in full counterbalanced manner, and the only manipulated factor was the level of facial attractiveness (all faces had direct gazes and neutral expression). Moreover, participants did not have any other task to do during viewing pictures, (when the pupillary reactions were recorded), and the required task evaluations were identical for all faces. Therefore, we had valid reasons to believe that increases in averaged pupil size were indeed stimulus-driven. More interestingly, the data did not show significant difference in pupillary dilations in response to lower than median levels of attractiveness (between first and second quartiles). This may suggest that the rewarding value of stimuli should be sufficiently large (over median level) to exceed the necessary threshold to trigger stimulus-related dilations. This finding was consistent with that of Winston et al. (2007) indicating increased pupil dilation in response to attractive faces (though they found this only with the male participants, probably because of the small group of females tested in their study, N= 6).

What can 'Pupillary Dilations' mean? One plausible explanation for increased pupillary dilations during viewing more attractive faces can be attention-driven phasic mode of activity in locus coeruleus (LC). Attractive faces, for various biologic and evolutionary reasons (Langlois et al., 2000), automatically attract our attention (note that this point is already embedded in the phrase of 'attractive') and bias our cognitive functions (Sui & Liu, 2009). In addition, neuroimaging studies have shown repeatedly that attractive faces have a high rewarding value since just looking at them can activate reward circuitry in the brain (Aharon, et al. 2001), particularly, in areas like orbitofrontal cortex (OFC), anterior cingulate cortex (ACC), amygdala and medial prefrontal cortex (mPFC). These areas are known to be involved in processing a wide range of rewarding stimuli and also have direct projections to the LC-norepinephrine (NE) system (Sara, 2009), which in turn, will modulate the pupils' diameter by its inhibitory effect on parasympathetic system (Koss, 1986). Therefore, stimulus-related pupillary dilations (e.g. in response to attractive faces) can index the attention-driven phasic mode of activity in the LC (Laeng, et al., 2012).

Why is the LC's phasic mode necessary during reward processing? The phasic mode of LC is induced by sufficiently strong inputs from the ongoing evaluations of costs and benefits in the reward and dopaminergic system. This phasic activation will reduce the LC spontaneous firing to noise, and result in a widespread, but temporally specific NE release in cortical sites responsible for task performance (Usher et al., 1999). Therefore, the phasic mode can facilitate selective attention, boost necessary cognitive mechanisms to follow the task-relevant events and eventually lead to the "exploitation" of the existent rewards (Aston-Jones & Cohen, 2005).

Moreover, Aston-Jones and Cohen (2005), integrating their gain theory of LC's function with Montague, Dayan, and Sejnowski's (1996) theory of dopamine (DA) function, proposed that the LC plays also a role in reinforcement learning when processing reward. In this respect, DA system can both trigger the phasic mode in the LC to generate reward-seeking behaviors and strengthen learnt reward-exploiting behaviors.

What is the adaptive function of LC's phasic activity, particularly in response to attractive faces? According to Aston-Jones & Cohen's gain theory (2005), the LC's adaptive function during each decision-making event is to optimize our 'reward-seeking behaviors' (contrary to the traditional view that considers the LC only as an arousal regulator). They suggested that the transition between two phasic and tonic modes of activity in the LC contributes to make a trade-off between ‘exploiting’ the available rewards and ‘exploring’ the new or more valuable rewarding sources in environment, respectively. When it comes to the attractive faces, mate choice appears to be a promising hypothesis to propose as an adaptive reason for their rewarding value. Evidence like the association between attractiveness and ‘parental care’, ‘reduced risk of contagion’ and ‘heritable resistance to disease’, has led some theorists to infer attractiveness as a signal of carrying ‘good genes’ (Møller & Alatalo, 1999). Therefore, attractive faces can signal a potential high quality mate, and trigger utility computations in the reward circuitry (e.g. OFC, ACC). Subsequently, they will activate the phasic mode of LC in order to facilitate reward-seeking behaviors and learning. The gender-dependent pupillary responses to facial attractiveness found in the current study may reflect this adaptive interpretation of LC’s function.

But why attractive faces are rewarding even when there is not any mate-choice motivation? Some of the present findings cannot be simply explained by mate choice processes. For example, studies have shown a preference for attractive faces between infants (Salter, 1998), as well as a general agreement across cultures and genders about the standards of attractiveness (Langlois et al., 2000). Consistent with the later evidence, we observed larger pupillary dilations in both men and women in response to more attractive faces of both sexes. Two accounts are suggested below for these findings.

One account refers to a well-documented stereotype that ‘what is beautiful is good’ (Eagly, et al., 2001) to explain the rewarding effect of attractiveness. Studies have shown that people associate attractiveness with positive and rewarding traits like intelligence, capability, kindness. Tsukiura and Cabeza (2010) provided neural evidence for the Beauty-is Good stereotype. Namely, an increased activation in mOFC was associated with rating a face as both more attractive and higher in goodness. This showed a shared brain region and activity during aesthetic and moral judgments for each presented face. This attitude was also observed in our demographic data, when participants reported capability, trust, friendliness, and experience as criteria (along with attractiveness) they used during making decision. However, all faces were neutral and participants did not possess any other information or familiarity with the portrayed people to be able to objectively attribute these traits.

Another account explains the rewarding value of attractiveness as a by-product of information processing mechanisms in the brain (Gillian Rhodes, 2006). In this respective, biological standards of facial attractiveness, like averageness, symmetry and sexual dimorphism induce hedonic experience because the brain is evolutionary adapted to process these features better or easier through learning and generalizing.

The gender-dependent pupillary dilations confirmed our hypothesis. In line with previous findings, our data demonstrated that pupillary changes can also index gender differences in processing hedonic stimuli. Laeng and Falkenberg (2007) found increased pupil sizes in women triggered by the faces of their sex partner. The seminal work of Hess and Polt (1960) showed 20% increase in pupil size when participants viewed nude pictures of the opposite sex. Porter et al.'s (2006) study revealed pupil dilation to faces with direct gaze but only between female participants. However, in the present study, we found increased pupil dilation in response to attractive faces from both female and male subjects, especially to opposite-sex faces.

This result can be explained by the higher attentional and arousal state during viewing faces of opposite sex, probably due to signaling mate quality or the general rewarding effect of attractiveness. Because of LC's role in arousal regulation and attention shifts (Sara, 2009), our data is consistent with the idea that the LC's activity is indexed by pupillary changes. Moreover, our male participants generated larger dilations, in comparison to females, which cannot be explained by males having anatomically larger pupils, since all of our measurements were baseline corrected. Interestingly, Winston et al.'s (2007) fMRI study showed an increased activity in anterior cingulate cortex (ACC) in only the male participants when looking at attractive faces of both men and women. Because ACC's activity regulates the internal autonomic states, they interpreted their finding as indicating a gender difference in arousal triggered by attractive faces. Therefore, our finding of general larger pupil dilations in men may confirm a higher arousal state in men, since the ACC has direct projections to the LC.

U-shaped pupillary dilations induced by the least and most attractive wine labels. In line with our hypothesis, pupillary dilations could index the level of attractiveness of wine labels as well as faces. A greater dilation induced by the most attractive labels would be consistent with previous studies on artistic stimuli. For example, Kuchinke, et al., (2009) observed higher pupil dilations induced by paintings rated as more beautiful. Carbon, et al. (2006) has found that highly innovative car designs were rated as higher attractive and induced bigger pupil dilation.

However, the greater pupillary dilations induced by the highly unattractive labels would seem to be in contrast to our previous finding with the unattractive faces. One explanation for different pupillary responses to the unattractive faces and unattractive wine labels can lie in the nature of stimuli. In fact, due to evolutionary and biological reasons, there are well-established standards for facial attractiveness that are common across cultures and genders. However, when it comes to the art and particularly to 'design', individual differences in preferences should be greater (Carbon, 2012). Therefore, this U-shaped pupillary dilation during observing wine bottles may reflect these individual differences.

Another explanation which seems more plausible is that both the highly unattractive and attractive label designs induce a greater arousal state, compared to the middle ranked labels. Studies have shown that both rewarding and aversive stimuli influence arousal and can engage the amygdala (Baxter & Murray, 2002). Aversive stimuli can also activate the ACC (Aston-Jones & Cohen, 2005). Considering the direct projections of amygdala and ACC to the LC, our wine labels' pupillary data provide confirming evidence for these interactions and a role of LC in arousal regulating. According to Berlyne (1971), aesthetic experiences are associated with an inverted U-shape physiological arousal. It means that both a sudden reduction and increase in arousal state can induce pleasure. This rewarding reduction in arousal is probably a result of discovering complexity in aesthetic stimuli.

Recently, Winston et al. (2007) found a U-shaped activation in amygdala in response to faces. However, their pupillary data in response to facial attractiveness did not show a U pattern, as also seen in the present study. Consequently, they interpreted their results as showing a role of amygdala in emotional and social perception rather than simply reflecting arousal effects.

No gender difference was found in pupil dilations when observing wine bottles. This highlights the important difference between the effects of social stimuli like faces and non-social stimuli on physiological responses.

Which features and processes may induce the aesthetic value of wine labels? Leder, et al. (2004) suggest in their five-stage model of aesthetic appreciation a compromising theory about how art can induce positive affective and 'self-rewarding' experiences. Since label designs and illustrations belong indeed to the 'art' category, their model seems relevant in explaining the aesthetic value of wine labels. According to them, just a 'pre-classification' of an object as art induces a biased pleasing expectation. Then in the first stage, perceptual analyses of features like contrast, color, symmetry, and complexity, make an artwork preferable. In this initial stage of processing one may experience pleasure due to processing those bottom-up features that the brain is evolutionary adjusted to perceive effortlessly.

In a second stage, one integrates the artwork to the memory, albeit implicitly. In this stage, features like 'familiarity' (mere-exposure), 'repetition' in exposure, 'prototypicality' (being representative of a category of objects), and 'peak-shift phenomenon' (exaggerated form of a familiar thing, like in caricatures) all can affect the aesthetic judgments. Our pupillary data, showing bigger pupil dilations in only alcohol drinkers in response to the real labels, may imply the effect of features like familiarity or prototypicality on their aesthetic judgments, leading to higher appreciations for well-formed designs.

The next stage is an explicit classification of an artwork, which depends on the knowledge of the perceiver. While an expert can infer much information from a label, a naive observer pays more attention to the illustrations and may interpret them just as they are depicted. Moreover, having more knowledge induces the pleasure of generalization since a person is able to categorize new examples, and therefore, it is a self-rewarding cognitive process. In the present study, we could not find more than one Italian wine expert to investigate these effects, although an attempt was made. Therefore, the present pupillary results may reflect more the participants' lack of knowledge about each brand of wine than their response to the meaning of the illustrations.

In the next stage, a process of 'cognitive mastering and evaluation' influences the aesthetic experience, since one evaluates how well his\her level of cognitive mastering can provide understanding and resolves the ambiguity of the stimuli. In this stage, 'personal taste' can strongly affect the aesthetic experience. Finally, Leder and colleagues (2004) propose that every aesthetic experience involves emotional processing due to the subjective feeling occurring during processing information in each stage.

The average pupil size increases during observing more expensive wine bottles. These pupillary results, along with data from economic decisions (showing that participants offered higher prices to the wines that were indeed more expensive in market), confirmed the stereotype or belief that more expensive goods have higher quality and are thus more rewarding. Our finding is also in line with fMRI studies showing that even illusory higher nominal (not real) economic values to an object can convey more rewarding value and simultaneously yield higher activation in the mPFC (Weber, et al., 2009). In another study, Plassmann, et al. (2007) allocated different prices (high and low) to the same type of wine and found that artificial more expensive attribution to a wine bottle can induce higher activation in mOFC, as well as higher subjective pleasantness ratings. They concluded that opposite to traditional economic theory, manipulating non-intrinsic properties such as price can override the real sensory representations such as wine taste. Therefore, it seems promising to expect that other non-intrinsic properties like design attractiveness play the same role in people's evaluations.

Number of eye fixations

The highly attractive faces triggered fewer eye fixations, in comparison to highly unattractive faces, but above-the-median attractive wine labels induced a greater number of eye fixations

than less attractive labels. Saccadic movements allow the foveal representation of a small part of environment which can be processed with greater visual resolution. Therefore, a greater number of eye fixations might indicate that participants need more information in order to make a decision when faces are less rewarding. This is consistent with findings showing that observing novel faces generated more fixations, when making judgments about face identity, in comparison to viewing famous faces (Barton, et al., 2006).

In addition to foveal representation, studies have shown that fixations and saccades are not just random, passive manifestations of perceptual mechanisms, and have an active role in information processing, particularly in judgment tasks (Barton, et al., 2006).

Henderson et al. (2005) proposed three ways by which eye movements per se can have a functional role in facial assessments which can also be explanatory for attractiveness assessments. 1) Encoding relational information between features by foveal representations, 2) computing these relations through the length of saccades 3) encoding important details that will be used in later decisions.

We also found that women searched for more information and generated greater number of fixations, but men's visual search was dependent on the gender, showing a longer gaze behavior when looking at female faces. Moreover, the effect of attractiveness on visual behavior does not depend only on the gender of perceiver, but also on the gender of the face. Our data showed that highly attractive female faces induced greater number of eye fixations, but higher levels of attractiveness in male faces triggered a smaller number of eye fixations. To the best of our knowledge, this is the first experimental evidence about the different effect of attractiveness of male and female faces on number of fixations.

Similar to the results for faces, the data on wine labels showed that women generated greater number of fixations, but in contrast to faces, the over-the-median attractive labels induced a greater number of eye fixations. Moreover, real wine labels (i.e., existent in the market) triggered greater number of fixations in women, but their price level did not affect number of fixations.

The difference between numbers of eye fixations on faces versus on wine labels, as the level of attractiveness increases, may originate from the nature of these stimuli. In fact, our attention and gaze point change all the time when we are uncertain about the sensory information or their outcome. Rewarding outcomes and our previous knowledge can also promote re-orientation and gaze changes (Henderson, 2006). The complexity and novelty of wine labels can be thought to be higher than that of human faces. Accordingly, more attractive wine labels, in comparison with less attractive ones, may attract attention in a way promoting search for more information. This assumption seems plausible according to the AOI analysis, showing that when the level of attractiveness increased, participants oriented their attention to the brand for longer time, probably seeking more beneficial information. The time course of each trial (10s) was sufficiently long to detect these differences in visual search during aesthetic experiences with human faces and objects. As Carbon (2012) explains, we live in a world which changes all the time, and therefore, our aesthetic taste changes dynamically whenever we counter and adopt new innovative objects. This may require more visual search.

Another reason for the difference between numbers of fixations with facial, versus design, attractiveness may be the different way they are processed. It is well known that faces are processed holistically and do not require many eye movements to provide foveal vision because relation between different parts of face is informative enough and are also obtainable from low spatial frequency information (Tanaka & Farah, 2003).

Although a holistic processing account may explain the difference between triggered number of fixations during viewing the more attractive faces and wine labels, it cannot explain the relation between number of eye fixations and levels of facial attractiveness. In fact, one implication of holistic theory is that we may not need any eye movements during face processing (Hsiao, 2013). However, studies using a time-restricted design have shown that eye movements do play a functional role in face recognition and judgment tasks (Hsiao & Cottrell, 2008; Henderson et al., 2005, Barton et al., 2006). In this sense, our data also suggest that different number of eye fixations were generated to make value-based decisions when the level of attractiveness changed.

AOI

Fixation duration

The average time of eye fixations was shorter when wine labels were more attractive. This finding is in accordance with the data from number of fixations, because, clearly, a greater number of fixations within a limited course time (10 s) trade off with shorter durations. At any rate, the present study may be the first to show that a wine label's graphics, followed by the name of wine and brand, induced the longest fixations. Moreover, when the level of attractiveness increased, participants looked at the brands a bit longer, suggesting that they oriented their attention to more informative parts of the label. Boudreaux and Palmer's (2007) behavioral study also showed that among different elements of label, the illustrations had the largest impact on both will to purchase and perceptions of so-called "brand personality". However, Atkin and Johnson (2010) found that there is a difference between American consumers with more and less wine knowledge in the label information that they use. In spite of that, the wines' brand tended to be the more important criterion for both groups. Moreover, they found gender differences in utilizing this information. For women, brand and label imagery prevailed, whereas for men regional information was more important. Our results did not confirm these findings.

Longer fixations (average percent time) to the more expensive wine. Interestingly, when the price level increased, the duration of fixations on the brand decreased but increased on the wine name and graphics. Since each wine company has a specific brand, but produces different types of wine with different names and different price, it may be natural if participants gaze longer at the name of wine, when the bottle is more valuable.

Finally, the results showed that the graphics of real labels triggered longer fixations in comparison to foil labels. This may indicate that the current wine market have correctly chosen the more eye-catching labels, at least within our data set.

The more attractive faces and eyes triggered longer eye fixations. This is also in accordance with our previous results indicating smaller number of fixations on highly attractive faces. While male faces induced greater number of eye fixations, female faces, particularly the eyes, induced longer fixations. Consistent with our results, Leder et al., (2010) found that fixation durations were longer to attractive faces and longest to female faces.

As expected, the longest fixations were on the eyes, nose and lips indicting that these areas may be more informative. Our AOI results are in line with several previous findings on face perception. For example, in Henderson, et al.'s (2005) study, the eyes, nose and mouth triggered the largest mean proportion of total time during free viewing learning. Saether, Van Belle, Laeng, Brennen, and Øvervoll (2009) found that participants fixated more on the eyes, nose and cheeks during a categorization task of the sex of faces. Kita et al. (2010) found longer fixation time for eyes and nose than mouth during an identification task. Hickman, Allen, Beck, and Speer (2010) also found that the eyes, nose, mouth, ear and chin, respectively, triggered the most frequent and longest fixations during viewing faces.

Why eyes? In the present study, the eyes appeared to be the most prominent feature in the face that triggered the longest fixations. In fact, the effect of eyes and the direction of gaze on facial perception and attractiveness have been reported frequently. Kloth, Altmann, and Schweinberger (2011) reported that people have a tendency to interpret direct gazes in highly attractive faces as holding eye contact with them, in comparison with unattractive faces. In addition, direct gazes can increase the extent to which participants perceive faces as attractive (Ewing, Rhodes, & Pellicano, 2010). These effects of the eyes on attracting attention can be explained by their rewarding value, and more importantly, by their adaptive role in the expression of social and emotional information. fMRI studies have also shown the involvement of areas like OFC and amygdala in processing gaze direction and its affective value (Emery, 2000). Moreover, foveal focus on the eyes may provide a better parafoveal representation of the whole face (Sæther et al., 2009).

What can longer fixations mean? According to the eye-mind theory (Just & Carpenter, 1980), 'there is no appreciable lag between what is fixated and what is processed'. Accordingly, these longer durations on specific features of faces or wine labels indicate which elements attracted the attention. However, Shimojo, Simion, Shimojo, and Scheier (2003) collected both eye tracking and behavioral results to show that gaze bias plays a role in preference formation. They found that gazing at either a specific face or abstract shape can lead to deeper sensory processing and a concomitant bias toward that stimulus to be chosen as more attractive. Since this gaze bias is continually reinforced in attractiveness tasks, it leads to a preference formation, rather than a merely selection, which they called the 'gaze cascade effect'. Thus, implicit orienting behaviors such as gazing can reflect our preferences and at the same time contribute to establish them. Our "economic" results confirmed that longer eye fixations to more attractive faces were associated with a preference for them as indicated by a willingness to pay higher salaries.

Laterality bias

Results from the present face study revealed significant longer fixations (mean percent time) on the left side of the faces than on the right, but only when the data taken from left-handed participants and particularly those participants that their script reading directions were from right to left (i.e. Persian or Arabic), were excluded. In fact, it was the direction of participants' first language that had a significant role (because the data including the left-handed subjects showed also significant interaction). There was a three way interaction between sex of face, level of attractiveness and side of face. These results indicated that when level of attractiveness increased, the left side of female faces triggered significantly longer eye fixations (for male faces, this was marginally significant). Such a left side bias is consistent with some of previous findings on processing faces (Heat et al., 2005; for a review see Hsiao, 2013).

Why the left side? There are several accounts that can explain a left-side bias in face processing. One explanation is based on the right hemisphere's dominance in face perception (Burt & Perrett, 1997; Rossion, et al., 2003). Since information from the left side of the visual field is processed in the right hemisphere, this may lead to a left side bias for faces.

Another explanation might be the presence of anatomical asymmetry in faces, so that the left side of the face may be more informative than the right side. This hypothesis seems to agree with the present findings, since such an asymmetry may cause the left side of faces to look more attractive (Zaidel, & Cohen, 2005).

Other influential factors are laterality and the writing direction of participant's first language, as we found in the present study. Heath, et al., (2005) found that both laterality and script direction can influence the left side bias toward faces. In their study, right-handed participants whose reading language was from left to right demonstrated the greatest leftward bias. Hsiao and Cottrell (2008) showed that the direction of facial scanning in both learning and recognition tasks was consistent with their participants' reading direction, which was from left to right.

In the present wine label study, we found longer and greater number of fixations on the left side of wine bottles, irrespective of the direction of written language or handedness of participants. This may suggest a generic left side bias in visual behavior.

Consistent with our result, Hsiao, et al. (2008) found left side bias in both face and object (Greeble) recognition task, after an initial learning phase. In another study, Hsiao and Cottrell (2009) found a left side bias between Chinese readers during perception of Chinese's 'mirror-symmetric characters' that was also reflected in their eye fixations behavior. Since this bias was not found between non-Chinese readers, they proposed that the left side bias may be a marker of visual expertise. This expertise account is also explanatory for the left side bias on faces, because we have processed both faces and language constantly since childhood, and therefore, both have become highly-learned skills. However, we did not find a side bias between alcohol drinkers, or "experts", relative to non-drinkers. Moreover, our participants did not consider themselves as knowledgeable when it comes to wine domain. Thus, this hypothesis might not be explanatory for our results.

However, a study by Mertens, Siegmund, and Grusser (1993) showed longer gaze on the left side of faces, but not on the left side of vases. Leonards and Scott-Samuel (2005) also found the left side bias only for face stimuli, but not for landscapes or fractals. Therefore, the language account appears to be more plausible for a left side bias in the wine label study, because there exist texts on all wine labels in our data set and these texts are written in a left to right language (i.e., Italian). A left side bias during processing English words is well-established (Brysbaert & Nazir, 2005).

Economic decisions

Participants were willing to pay higher payoffs to the more attractive faces and wine labels. Our data showed parametric increases in the level of salaries as a function of increase in facial attractiveness. Moreover, participants attributed more capability to the more attractive faces. This is in line with previous behavioral studies showing that attractiveness bias judgments and economic decisions in professional situations (Hamermesh & Biddle, 1994; Mobius, et al., 2005). It is worthy to mention that the majority of our participants were Norwegians (N=30), and a notion of equality is well rooted in this society. In fact, many of subjects reported having difficulty to decide about different salaries on the basis of considerations of fairness and equality. Nevertheless, as clearly shown in the present results, there were significant distinctions in estimated salaries for faces with different level of attractiveness. This suggests that attractiveness effects override other top-down or socially normative goals.

Thus, these economic results together with automatic increase in pupillary dilations and specific pattern of eye fixations during viewing more attractive faces may provide more evidence for theories suggesting that attractive faces are perceived automatically and unconsciously (Olson & Marshuetz, 2005; Werheid, Schacht, & Sommer, 2007; Hooff, Crawford, & Vugt, 2010), and they have bottom-up effect on attracting attention and cognitive judgments (Sui & Liu, 2009). This finding is more notable when the timeframe of this study is taken to the consideration. In fact, attractive faces induced spontaneous pupillary responses, overrided top-down values, and influenced economic decisions that were nor relevant to it, all within the 10 s presentation time.

Similar evidence was gathered in the wine label experiment. Most of our participants considered themselves as either naive or ignorant when it comes to the wine knowledge and they did not have previous knowledge about the quality of each brands. Moreover, almost half of participants (N=21) reported that their income level was one of their criteria to make economic decisions and in fact, the income level of 28 participants corresponded to the minimum income (under 10,000 Kr) in Norway. However, we observed clear increases in the prices offered for the more attractive labels. Therefore, it appears plausible to accept that the level of attractiveness in non-social rewarding stimuli, as well as social stimuli, can override rational considerations, induce spontaneous pupillary responses, and bias the economic decisions, even when participants cannot experience the hedonic influence of alcohol (as for non-alcohol drinkers), and even when they have enough time to elaborate (10s).

Knutson, et al., (2007) in a blocked design fMRI study investigated the neural structures involved in ‘purchasing decisions’. Their results showed increased activation in mPFC during evaluation of offered prices. During presentation of product, activation in NAcc was accompanied with preferences and subsequent shopping behavior. In contrary, Plassmann, et al. (2007) showed that 'the willingness-to-pay' may be "computed" in mOFC, where one evaluates the rewarding value of decisions. These different neural activities probably result from subtle differences in their tasks, which require different computational mechanisms. However, they may clarify which neural structures may have been involved during decision making in our study. Indeed, they are in line with our assumption that pupillary data can track the LC's activation, given that all of the above-mentioned areas have projections to the LC. Therefore, either due to effect of attractiveness, or the task computations, this study may have successfully tapped into the LC's phasic mode activity.

Limitations

Despite the many advantages of the present study (e.g., a large set of stimuli spanning well distinct levels of attractiveness, counterbalancing the conditions, an appropriate sample size, etc), , it clearly had several limitations. For instance, we only investigated the participants' willingness to pay, and this can be different from real choices made in real situations. In addition, the population of non-drinkers did not equal that of alcohol drinkers. Therefore, some of the null effects may be due to insufficient statistical power and representativeness. Moreover, our participants did not include Italian wine experts as a comparison group; in fact, the majority of the participants considered themselves as non-knowledgeable about wines. Although fact is highly beneficial to investigating the effect of label attractiveness per se, it does make possible to study the effects of expertise on the same judgments as well as oculomotor behavior. More importantly, it is possible that other factors (rather than attractiveness) or a combination of factors in our stimuli contributed to trigger these stimulus-driven pupillary dilations. Since this study was the first investigation on the effect of parametric increase in the level of attractiveness in faces and wine labels on pupillary dilations, further research is necessary to ensure that the present findings are replicable.

Implications

The present study has relevance for several lines of research, from cognitive science, psychophysiology, to neuroeconomics and marketing.

In relation to marketing and neuroconomics, we were successful in identifying aesthetic features that have a strong effect on choices and willingness to pay, despite they might be not related to the rational utility of people's decisions. The detection of these features may enable us to predict individuals' behavior in daily situations and, particularly, in the market.

Moreover, these findings may provide indications for marketing in order to influence peoples' purchase behavior by manipulating these visual cues. Of specific interest for the neuroeconomic domain, we provided both behavioral and reliable neurophysiological indexes, pupillary dilations and eye fixations, to show how the visual salient features of the faces and objects can influence economic decisions, despite they may be irrelevant to the task. Simultaneously, our results demonstrated that economic value of goods (real price of wines) trigger spontaneous physiological responses. In relation to psychophysiology research, our findings show how the hedonic values of (social and non-social) stimuli can trigger attention and physiological responses. They also reveal gender-dependent and lateralized effects on these physiological markers and cognitive evaluations.

However, perhaps the most important implication in this study was providing clear evidence that the pupillary responses can index the parametric levels of attractiveness in both social and non-social stimuli. In turn, these responses may tap the LC's phasic activity, thus also providing us with a privileged window onto changes in neuromodulatory function that may be of great relevance for understanding motivation and attentional responses to hedonic stimuli.

Conclusion

The present study may provide the first empirical evidence about the effects of a parametric increase in attractiveness of both human faces and wine labels (i.e., social and non-social rewarding stimuli) on pupillary responses. In addition, it extends our knowledge about how aesthetic values of both social and non-social stimuli influence the attention and oculomotor behavior. The study gathers new evidence about the effect of hedonics on biasing value-based decisions. Moreover, it provides empirical evidence for the power of the internal features of the faces (i.e. eyes, nose and mouth) in attracting attention and how this capture increases parametrically with hedonic value when participants are asked to make economic decisions. We were able to detect reliably those parts of wine labels that a participant mostly scrutinizes prior to evaluating economic value. This study is also a witness of the influence of gender, alcohol consumption, on the above behaviors as well as revealing laterality effects. Finally, we were able to compare real versus estimated values and comparing real label designs to foil ones that do not exist in the market.

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Appendices

Appendix 1. Quartiles of (mean) ratings on facial attractiveness for 114 colored female faces taken from female and male participants; Table below, descriptive information of subjects.

Female faces (total 114 faces)				
Evaluated by Both Genders				
	Quartiles			
	1st	2nd	3rd	4th
Range of Quartiles	~3.66	3.66 ~ 4.25	4.25 ~ 4.81	4.81~
Number of Faces	29	28	28	29
	max = 7.20	min = 2.04	mean = 4.23	
Evaluated by Female				
	Quartiles			
	1st	2nd	3rd	4th
Range of Quartiles	~3.57	3.57 ~ 4.38	4.38 ~ 5.09	5.09~
Number of Faces	29	28	28	29
	Max = 8.65	Min = 1.68	Mean = 4.37	
Evaluated by Males				
	Quartiles			
	1st	2nd	3rd	4th
Range of Quartiles	~3.54	3.54 ~ 4.16	4.16 ~ 4.64	4.64~
Number of Faces	29	28	28	29
	Max = 6.50	Min = 2.06	Mean = 4.12	

a. Range of ratings in each quartile of attractiveness (first from up, across all participants, across female subjects, and s, and across male subjects)

Participants Descriptive Information (Medicine Students)			
		Age	
	n	***Mean***	***SD***
Female Ps	21	23,3	5,8
Male Ps	20	26,2	11,8
total	41	24,7	9,2

b. Descriptive information about the sample of participants

Appendix 2. Quartiles of (mean) ratings on facial attractiveness for 94 colored male faces taken from female and male participants; Table below, descriptive information of subjects

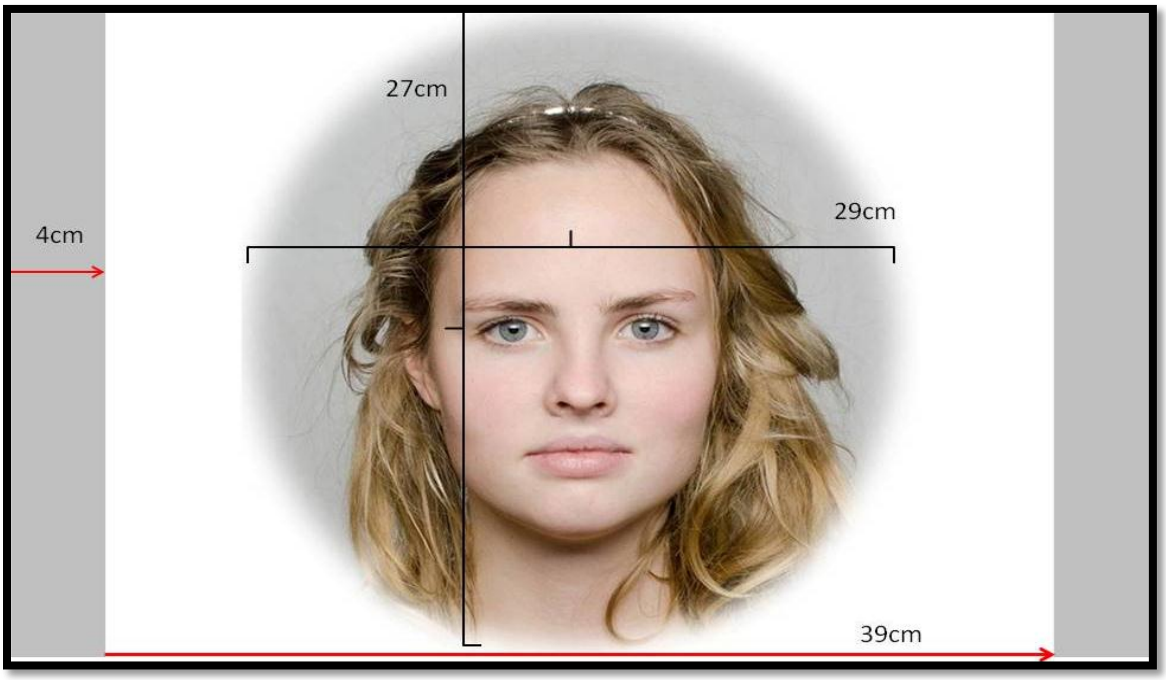
Male faces (total 94 faces)				
evaluated by both gender				
	Quartiles			
	1st	2nd	3rd	4th
Range of Quartiles	~3.25	3.25 ~ 3.64	3.64 ~ 4.28	4.28~
Number of Faces	24	23	23	24
	max = 6.15	min = 1.88	mean = 3.76	
evaluated by females				
	Quartiles			
	1st	2nd	3rd	4th
Range of Quartiles	~3.21	3.21 ~ 3.77	3.77 ~ 4.54	4.54~
Number of Faces	24	23	23	24
	max = 8.99	min = 0.35	mean = 3.89	
evaluated by males				
	Quartiles			
	1st	2nd	3rd	4th
Range of Quartiles	~3.19	3.19 ~ 3.63	3.63 ~ 4.18	4.18~
Number of Faces	24	23	23	24
	max = 5.55	min = 1.95	mean = 3.70	

a. Range of ratings in each quartile of attractiveness (first from up, across all participants, across female subjects, and s, and across male subjects)

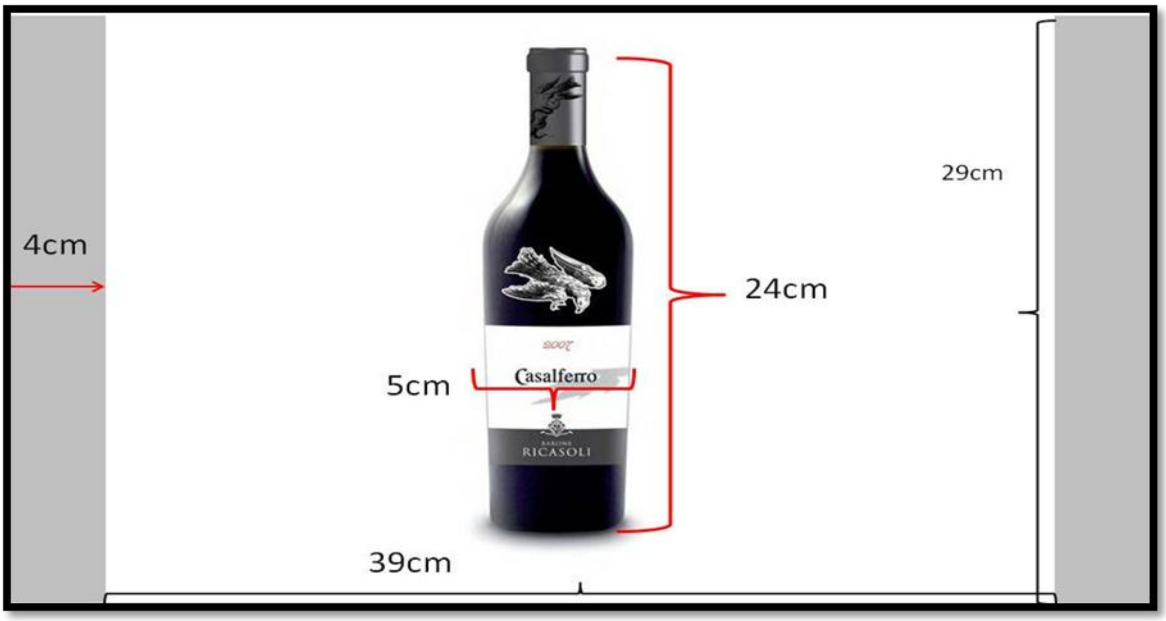
Participants Descriptive Information (Medicine Students)			
		Age	
	n	***Mean***	***SD***
Female	21	23,3	5,8
Male	20	26,2	11,8
total	41	24,7	9,2

b. Descriptive information about the sample of participants

Appendix 3. An illustration of presented stimuli at the computer screen



a. An example of size and location of face stimuli presented at the computer screen



b. An example of size and location of wine stimuli presented at the computer screen

Appendix 4. Quartiles of (mean) ratings on a) attractiveness for 40 wine labels and b) real price (in market) of wine bottle

	Min	Max	Range size	Number of bottles
1st quartile (least Attractive)	3.49	4.28	0.8	10
2nd quartile	4.28	4.795	0.5	10
3rd quartile	4.795	5.295	0.49	10
4th quartile (most Attractive)	5.295	6.15	0.87	10

a) Range of ratings in each quartile of attractiveness in wine labels, rated by 40 participants (N=20); Total Min= 3.49; Total Max=6.15; Total Mean= 4,78

	Min	Max	Range Size	Number of Wines
1st quarlite (cheap)	44,75	< 58.59	13,84	1
2nd quartile	58,59	< 62.99	4,4	4
3rd quartile	62,99	< 201.41	138,42	2
4th quartile (expensive)	201,41	442,00	240,59	3

b) Range of ratings in each quartile of real price (in market) of wine bottles in wine labels,

Highest price in NOK: 442,00; Lowest price in NOK: 44,75

Appendix 5. A copy of paper personal questionnaire, page1

Please provide the following information.

(1) Basic information about your self

Name: ____________________. Age: _____.

Sex: _________. Nationality: ______________. First Language: ____________________.

(2) If you are not born in Norway, how long have you been living in Norway?

_______ years

(3) Which hand do you use to write/draw?

□ Left □ Right

(4) <i> If you are religious: are you a···?

□ Christian □ Muslim □ Jewish □ Others (____________)

<ii> If you are religious:

- How much do you follow your religious principles in practice?

□ Not at all □ A little □ Moderately □ Very much

(5) <i> How much are you familiar with salary levels in Norway?

□ Not at all □ A little □ Moderately □ Very much

<ii>Have you ever been in charge to hire personnel?

□ Yes □ No

(6) <i> Do you drink alcoholic beverages?

□ Yes □ No

<ii> Which one do you prefer to drink?

□ Beer □ Wine □Spirit □Other (__________)

(7) If you drink alcoholic beverages:

<i> Do you also drink wine?

□ Yes □ No

<ii> When do you drink wine most often?

□ Socially □ At regular meal time □ Both

<iii> How often do you drink?

□ Every day □ 3-5 days per week □ Just on the weekends

□ Couple of times per month

<iv> Which one do you prefer?

□ Red wine □ White wine

Appendix 5. A copy of paper personal questionnaire, page 2

<v> When it comes to wine knowledge, do you consider yourself a person who is:

- □ A wine expert
  (e.g., I read wine magazines, I took courses as sommelier, I belong to a "wine tasting" club. etc.).
- □ Knowledgeable
  (e.g., I know what a good wine is and I like to spend a bit more for a better wine).
- □ Naive
  (e.g., I have little knowledge about wines).
- □ Ignorant
  (e.g., I have no knowledge about wines).

<iv>Which types of wine do you know best (or drink most)?

□ French □ Italian □ Spanish □ German □ South African
□ Australian □ American □ Chilean □ Other (   )

(8) <i> Please indicate your monthly income (in NOK, pretax).

□ Under 10,000 □ 10,000 – 20,000 □ 21,000 – 30,000 □ 31,000 – 45,000

<ii> How much would you typically pay for a wine bottle at Vinmonopolet (in NOK)?

□ 70-100 □ 110-200 □ 210-300 □ 310-450

(9) When you chose a wine price during the task, what do you believe were the criteria you used to decide the price of each wine bottle? If you have considered more than one criterion, you can use ordinal numbers (e.g., 1, 2, 3···) beside each criterion to indicate their order.

□ Design of the bottle or label □ Name of the wine
□ Statistics basis (probability) □ Your income level
□ Your familiarity with that specific wine □ Other (   )

(10) <i> When you chose a salary level during the task, what do you believe were the criteria you used to decide the level of salary you would offer to each person? (You can again write ordinal numbers beside them)

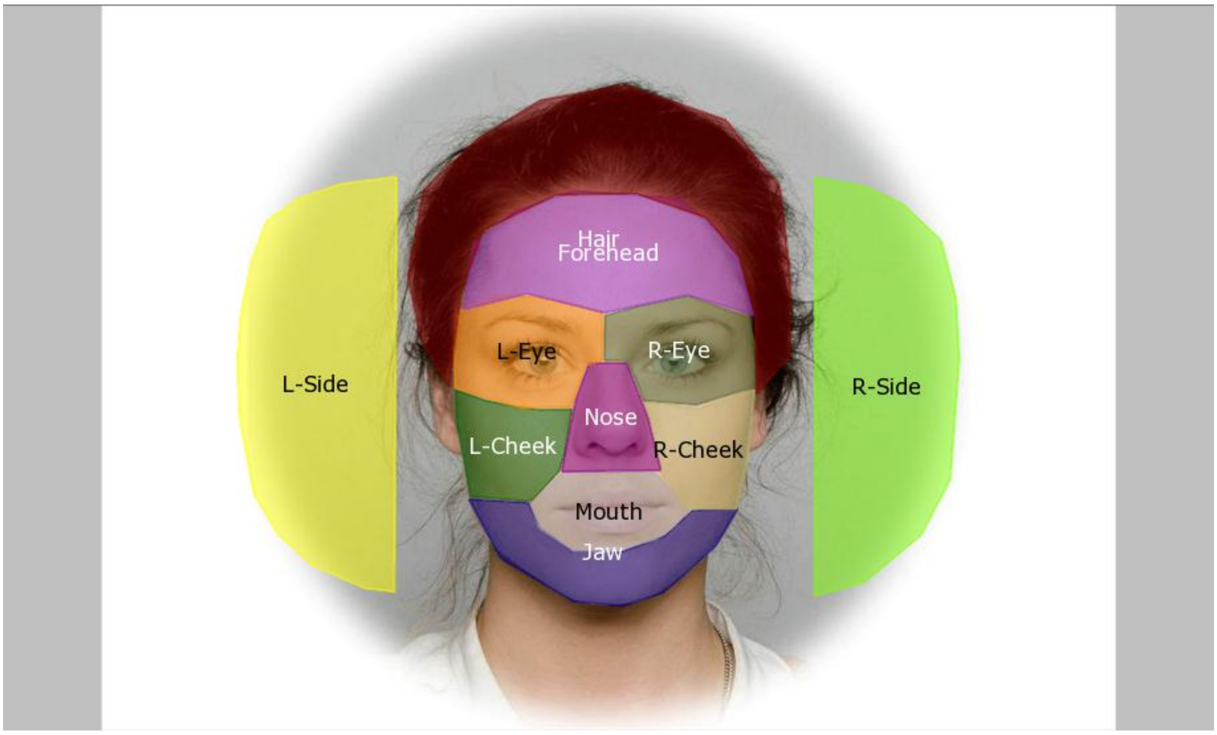
□ Your knowledge about salaries □ Statistics basis (probability)
□ How attractive they look □ How friendly they look
□ How trustworthy they look □ How experienced they look
□ How capable they look □ Their gender
□ Their age □ Other (   )

<ii> Which gender do you think is most suitable to work in wine store?

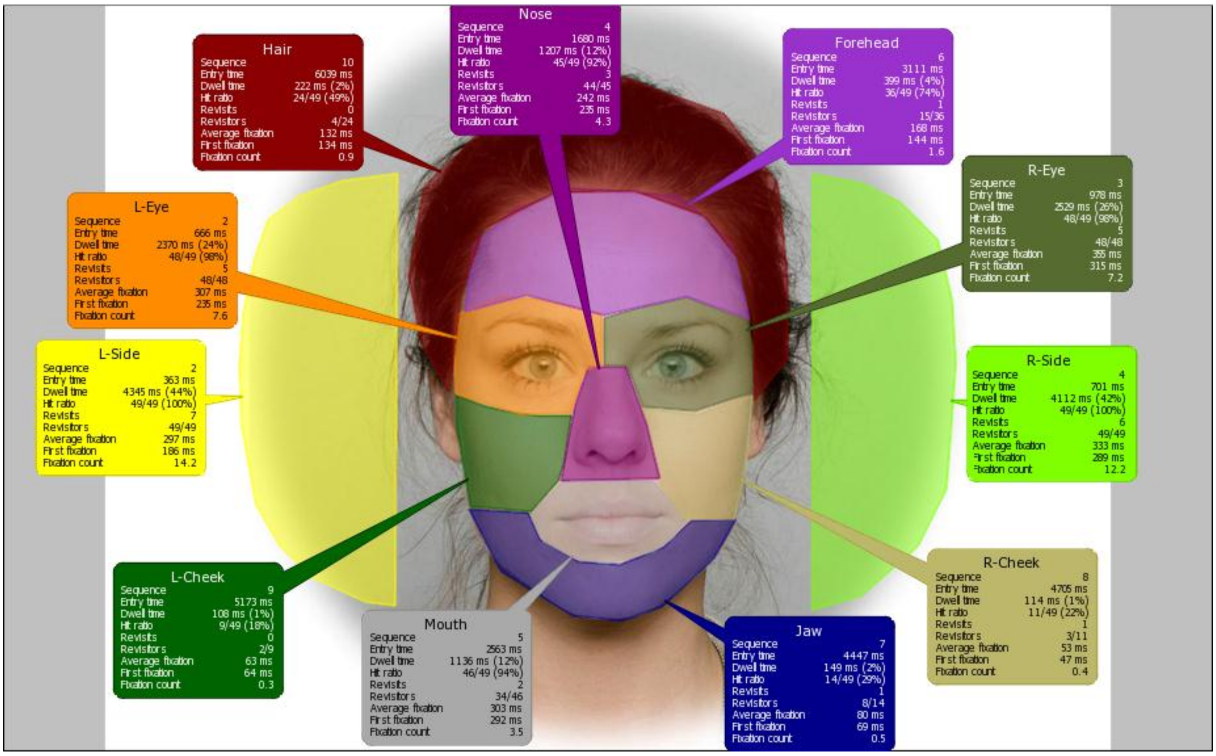
□ Women □ Men □ Both

Thank you for your cooperation! ☺

Appendix 6. A sample of Areas of Interest (AOIs) in face stimuli (a) and mean fixation durations in each AOIs (b)



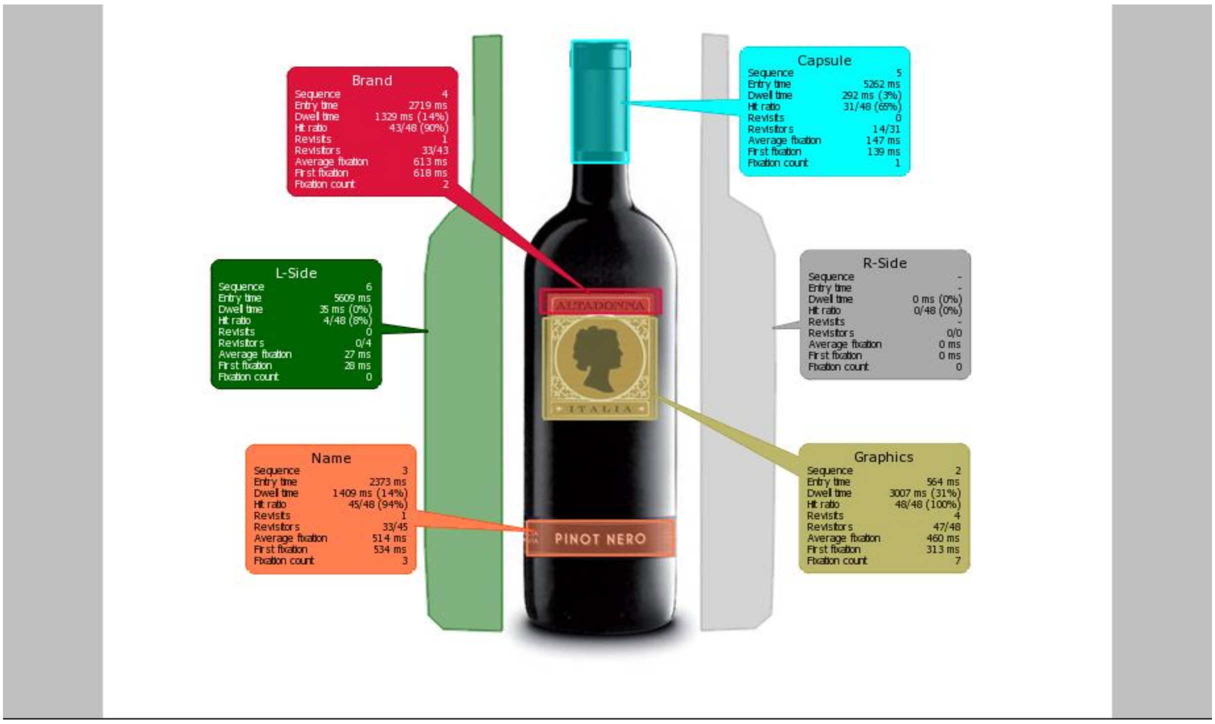
a) Eleven defined AOIs in face stimuli



b) Mean fixation duration in each AOIs across all participants in a sample face, taken from Key Performance Indicators application in Bee-Gaze software

Appendix 7. A sample of Areas of Interests in wine bottle stimuli (a), and the average fixation duration on each AOIs (b)

a) Six defined AOIs in wine stimuli



b) Mean fixation duration in each AOIs across all participants in a sample wine, taken from Key Performance Indicators application in Bee-Gaze software

Appendix 8. Heat (a) and Focus (b) map of AOIs in a sample face across all participants

a) Heat map of AOIs in a sample face which illustrates clearly the eyes were most attracting part of eyes**.**

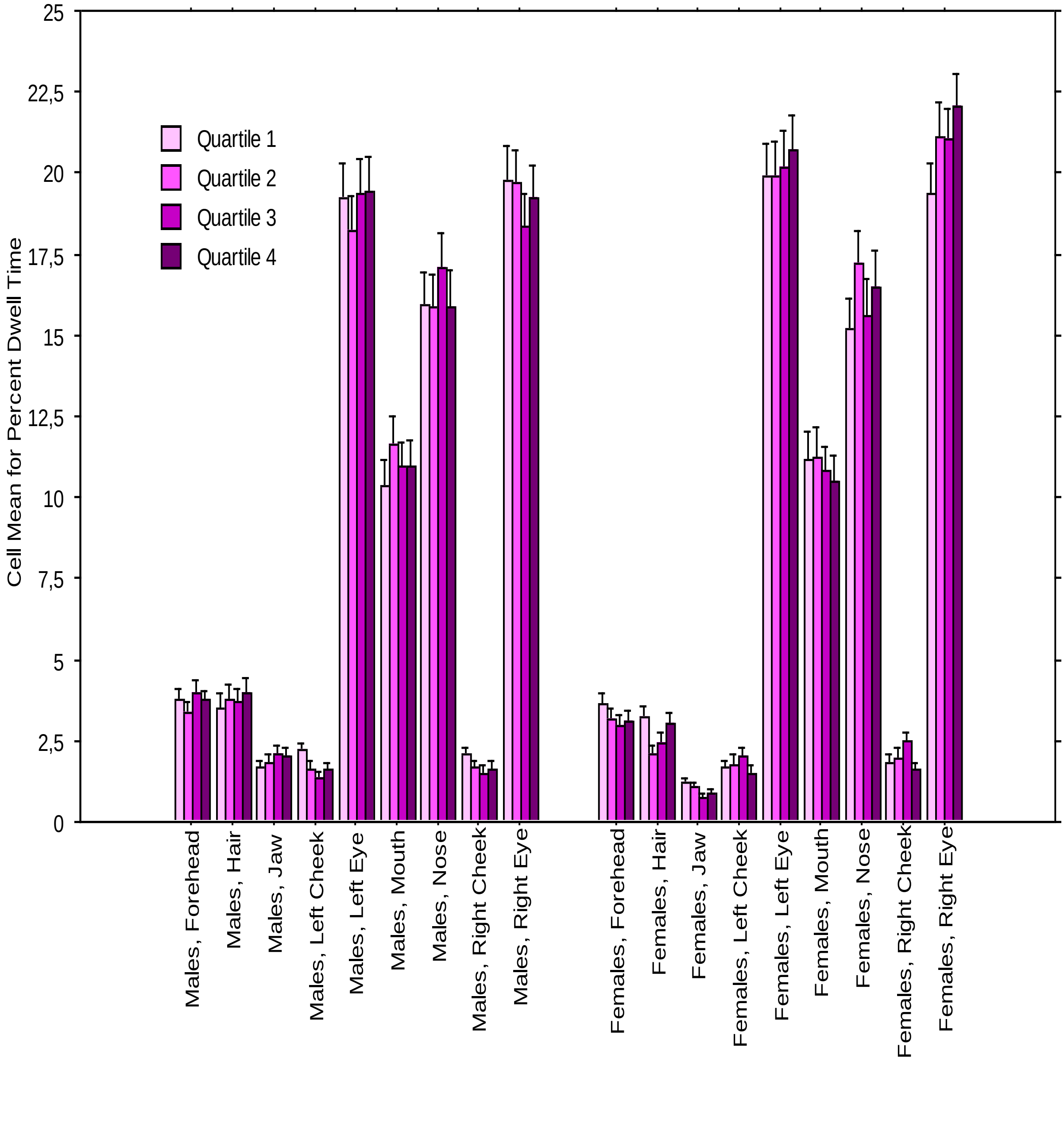
b) Focus map of AOIs in a sample face which illustrates internal facial features are most attracting parts and informative to make decision

Appendix 9. Heat (a) and Focus (b) map of AOIs in a sample wine bottle

a) Heat map of AOIs in a sample face across all participants which illustrates clearly the eyes were most attracting part of eyes

b) Focus map of AOIs in a sample face across all participants which illustrates internal facial features are most attracting parts and informative to make decision

Appendix 10. Average fixation duration in each AOIs in faces as a function of attractiveness and sex of face; Left side, Male faces; Right side, Female faces



Appendix 11. Tables present the elements that participants reported as their four criteria, respectively to make economic decisions a. for faces; b. for wine bottles

	First Criteria	**Second Criterion**	**Third Criterion**	**Fourth Criterion**
Knowledge about Salaries	1	3		
Attractiveness	6	10	8	6
Trustworthy	7	10	5	1
Capability	12	7	8	3
Age	9	4	9	6
Friendliness	6	9	8	4
Experience	6	6	4	4
Statistics Basis	2	1	1	
Gender			2	3

a. The table presents the nine elements that subjects could choose as one of their four criteria (respectively) to decide about salaries (for faces).

	Design of Label	Wine Name	Income Level	Familiarity	Year of Production	Statistics Basis
First Criteria	27	1	12	2	3	2
Second Criterion	15	4	7	5	3	2
Third Criterion		6		4	2	3
Fourth Criterion	1	1	2		1	

b. The frequency of six elements as one of subjects' four criteria to decide on the prices (for each wine bottle).