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APPRAISALS INFLUENCE EYE PUPIL SIZE: THE EFFECT OF GOAL TYPE AND GOAL CONGRUENCE

Master's thesis

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Running head: Appraisal dimensions and pupillary responses

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Appraisals Influence Eye Pupil Size: The Effect of Goal Type and Goal Congruence

Abstract

This thesis attempted to investigate the effects of appraisal dimensions on pupillary movements. Three appraisal dimensions were under investigation: goal relevance, goal type and goal congruence. Three hypotheses were formulated. Pupil dilation a) differs in neutral and relevant events; b) depends differently on wins and losses; c) is affected by goal conduciveness and goal obstructiveness. A novel research paradigm was used to test these hypotheses. Instead of picture stimuli we relied on perceptually simple stimuli (Landolt circles) which were coupled with affective meaning. To that end we used the monetary incentive delay task (MID) where the stimuli were associated with three types of events: gains, losses, neutral. The conditioning in the experiment was successful. Pupil dilation showed a difference between neutral and relevant events. As predicted, the results confirmed that goal type has an effect on pupillary reactivity. To a degree goal conduciveness also demonstrated the pattern predicted, in that pupil reactivity changed, but only in approach conditions (conditions "*you won*" and "*you did not win*" differed significantly).

Keywords: appraisal, pupillometry, incentives, reward, monetary incentive delay task

Hinnangud mõjutavad pupilli suurust: eesmärgi tüübi ja eesmärgiga ühilduvuse mõjud

Kokkuvõte

Magistritöö uurib, kuidas hinnangud mõjutavad pupilli reageerimist. Kolm hinnangute dimensiooni on uurimise all: eesmärgi olulisus, eesmärgi tüüp, eesmärgiga ühilduvus. Püstitati kolm hüpoteesi. Pupilli reageerimine: a) on erinev neutraalsetes ja olulistes tingimustes; b) sõltub kaotustest ja võitudest; c) on mõjutatud eesmärgiga ühilduvast-mitteühilduvast tulemusest. Uurimiseks kasutati uudset paradigmat. Pildistiimulite asemel kasutati visuaalselt lihtsaid stiimuleid (Landolti ringe), mida seostati afektiivsete väärtustega. Selleks rakendati motivatsioonilist ülesannet (MID), kus stiimuleid seostati afektiivse väärtusega kolme tüüpi sündmuste kaudu: võidud, kaotused ja neutraalsed sündmused. Seoste tingimine oli eksperimendis edukas. Pupilli reageerimine oli erinev neutraalsetes ja olulistes tingimustes, mis põhjustasid pupilli laienemist. Eesmärgi tüüpide vahel tuli samuti erinevus pupilli suuruses esile. Eemärgiga ühilduvad ja mitteühilduvad vihjed avaldasid erinevat mõju ainult võiduga seotud tingimustes.

Märksõnad: hinnangud, pupillomeetria, ajend, tasu, motivatsiooniline ülesanne

Introduction

There is a famous proverb that the eyes are the window to the soul. The core concept of the saying (although in a more humble form) has found its way into science. Research has shown that we can know something about the workings of the mind from gaze data or pupillary movements. Eye tracking has seen a growing interest in many research areas (cognitive psychology, developmental psychology, marketing). One of the main functions of pupillary movement is to control the amount of light entering the eye (Beatty & Lucero-Wagoner 2000). Pupillary reactivity has been also linked to various psychological processes (Beatty & Lucero-Wagoner, 2000; Goldwater, 1972). From the perspective of affect research it is interesting to note that pupillary reactivity has been linked to emotionally salient or interesting visual stimuli (Hess & Polt, 1960). The main explanation in recent research is that one of the main factors modulating pupil responses is emotional arousal, not valence of the stimuli (Bradley, Miccoli, Escrig & Kang, 2008). However, it is unclear whether pupil dilation is a direct consequence of affective arousal or is driven by some of the mechanisms underlying arousal, such as affective appraisals. To shed light on this question, this study adopts an experimental paradigm that enables to measure pupillary reactivity in response to variance in three important appraisal dimensions – goal relevance, goal type and goal congruence.

In this thesis I argue that affective influences on pupillary reactivity should be studied in relation to experimental manipulations of affective components such as cognitive appraisals. Affective states are complex and multifaceted phenomena which have several different components: subjective experience, expressive behavior, peripheral physiological responses, cognitive appraisals (Gross & Barrett, 2011). Different theories emphasize different aspects of this architecture (Gross & Barrett, 2011). From the perspective of core affect (Watson & Tellegen, 1985, Russel, 1980) there are two main factors that modulate affective experience - valence and arousal. Previous research into pupil responses to affect manipulation has mostly focused on those two factors. Other theories emphasize factors such as cognitive appraisals, which in their view can trigger basic biological affective responses. This paper takes the same view – affective states arise from person-situation interactions when individuals appraise the situations in light of their goals and concerns (Gross & Barrett, 2011; Elsworth & Scherer, 2003, Moors, Ellsworth, Scherer, & Frijda, 2013). This approach to affective states is more detailed than the two-dimensional view and allows for a more precise analysis of affective influences on pupillary reactivity. From the viewpoint of appraisal theory appraisals can cause changes in all other affect components (Gross &

Barrett, 2011; Elsworth & Scherer, 2003, Moors, Ellsworth, Scherer, & Frijda, 2013). Therefore appraisal dimensions could also be the sources of modulating effects on pupillary reactivity. To test this idea, a game-like task was used to associate appraisals with certain stimuli. The task was designed to investigate how different appraisal dimensions (such as goal relevance, goal type and goal congruence) alter the pupil's response to the different gain-related and loss-related situations.

Research With Affect and Pupil

In pupillary research there are several methods used for inducing emotional states, for example images (Hess & Polt, 1960; Aboyoun and Dabbs, 1998; Bradley, Miccoli, Escrig and Lang, 2008), sounds (Partal and Sarukka, 2003), reward cues (Chiew and Braver, 2013). One of the main methods has been the use of images with standardized valence and arousal ratings. Aboyoun and Dabbs (1998) used as stimuli pictures of clothed and naked individuals. Their study showed that pupil dilation ensued after the presentation of nude pictures, the effect was present for both female and male participants. The results demonstrated that apart from arousal, the novelty of the nude picture was also an important factor. In their study Bradley, Miccoli, Escrig and Lang (2008) presented pleasant, neutral and unpleasant pictures. The pupil dilated when participants viewed pleasant or unpleasant stimuli, compared to neutral pictures. They concluded that arousal prompts pupillary responses. Pupillary reactivity is also sensitive to auditory stimuli. Partal and Sarukka (2003) measured pupil size while participants listened to negative, positive and neutral sounds. Pupil size was significantly larger in negative and positive conditions than neutral conditions. They concluded that arousing stimuli is the main factor modulating pupil size in auditory conditions. This study is especially interesting because it does not use visual cues, thus demonstrating clearly that the pupil response is caused by emotional processes not by differences in the physical characteristics of the stimuli. A more dynamic approach was used by Chiew and Braver (2013). They used motivational manipulation with two kinds of incentives: a green square which signaled neutral trials and a green dollar sign which signaled the reward trial. Reward incentives were associated with an increase in pupil dilation. The methods described have produced quite similar results. The main pupil size modulator seems to be arousal, although as the Aboyoun's and Dabbs' (1998) study shows we should not hastily conclude that arousal is the only factor influencing pupillary responses.

There are several problems with studying pupillary responses to affective states. As the pupil is very sensitive to light conditions (MacLachlan & Howland, 2002), results of a study can be easily confounded by differences in stimulus luminosity. Finding appropriate visual stimuli that minimize different sources of confounds (luminosity, stimulus valence and arousal ratings) can be quite a difficult task. In addition to introducing perceptual confounds, picture and sound stimuli that differentiate emotional categories only in wide dimensions such as valence and arousal also do not give a detailed overview of affective influences on pupillary reactivity. Previous research has mostly focused on one or two broad dimensions: nude vs non-nude (Aboyoun & Dabbs, 1998), reward vs non-reward (Chiew & Braver, 2013), valence vs arousal (Bradley, Miccoli, Escrig and Lang, 2008; Partal and Sarukka, 2003).

Research With Cognitive Pprocesses and Pupil

The study of pupil responses to affective stimuli needs to take into account that there can be also other causes for changes in pupil size. In addition to previously mentioned ones, pupil size is an effective index of autonomic activity, pupil dilation may reflect such processes as sensory stimulation, mental activity and attention (Goldwater, 1972). For example, the pupil responds in a systematic manner to memory load (Beatty, Kahneman, 1996), mental calculations (Ahern & Beatty, 1979), and attentional effort (Kang, Huffer, & Wheatley, 2014). Beatty and Kahneman (1996) showed that by increasing the number of digits to be remembered the pupil diameter will increase. This correlation was found in recalling numbers from short-term memory as well as from long-term memory. Ahern & Beatty (1979) used mental arithmetic problems to show that cognitive capacity demands during mental activity and task-evoked pupil size are negatively correlated. Kang, Huffer, and Wheatley (2014) showed that pupillary response is different in trials where participants are attending to the stimuli, compared to trials where they are not attending to exogenous cues. Research into affective influences on pupil dilation has to take into account the effect of cognitive processes, otherwise it can be a major confounding factor in the experiment. Cognitive activity can overwrite the emotional arousal effect on the pupil, as arousal can be significant only when cognitive demands are minimal (Stanners et al., 1979, as cited in Võ et al., 2008). To minimize the effect of cognitive processes this experiment used a simple choice task in all trials.

The Solutions for Previous Problems

In this thesis I propose a solution for both aforementioned problems encountered in previous research. The use of perceptually simple stimuli which can be coupled with affective meaning allows to bypass the problem with balancing stimulus luminosity and also helps to use stimuli that do not have remarkable affective value before the experiment (Kliegl, Watrin, & Huckauf, 2014). A recent study used Landolt circles (simple circles with a gap in different locations) as target stimuli (Kliegl, Watrin, & Huckauf, 2014). They associated certain Landolt circles with neutral images and others with emotional images. The time perception task used in the study demonstrated that the effect of emotional temporal overestimation remains even when only the conditioned circles are assessed.

Instead of two primary dimensions such as valence and affect I propose that pupillary responses are related to specific appraisals. There are many opinions about the number and essence of appraisal factors, but a core set of appraisal factors are considered to include goal relevance, goal congruence, expectancy or novelty, coping potential or control, agency, and intentionality (Ellsworth & Scherer, 2003). Specific emotions arise from the combinations of different values on appraisal variables (Moors, 2009). This study focuses on three appraisal dimensions: goal relevance (neutral vs relevant); goal type (gain vs loss) and goal congruence (obstructive vs conducive).

Goal relevance is a general dimension, which is especially important because if there is a difference between neutral and relevant states then the experiment was successful in inducing affective states.

The second appraisal dimension under investigation is goal type. Some authors argue that emotion is founded on motivational neural circuity, aversive and appetitive cues modulate affective states and are the underlying factors of negative and positive affects (Lang, 2010; Lang & Bradley, 2010). Chiew & Brewer (2013) used only reward incentives in their experiment. The present study tested if approach (gain) and avoidance (loss) activation modulate pupil dilation. If goal type were a significant predictor of pupil dilation the changes in pupil size should follow the distinction between win-related states and loss-related states.

The third appraisal dimension I investigate is goal congruence of outcomes. Goal congruence has been considered as an underlying dimension of valence states – producing both pleasant and unpleasant affective states (Roseman, 2013). Negative affect should be the result of goal-obstructive circumstances, positive affect should be produced by goal-conducive outcomes. If this dimensions underlies pupil dilation effects, we would expect pupil dilation during not winning (obstructed approach) to be similar to the effect of losing (obstructed avoidance) and pupil dilation during not losing (conduced avoidance) to resemble winning (conduced avoidance).

Taking this approach gives us an opportunity to look deeper into the processing of affective stimuli. The main idea is to ask if the mechanisms believed to produce qualities of subjective feeling such as arousal can trigger pupillary responses.

The Present Research

In summary, existing research on affect and pupil dilation shows that the main modulator of this process might be arousal, but two sources of uncertainty remain in published studies. First, arousal has a strong effect on pupil dilation, but may not give a complete picture of the affective influence. The stimuli used in previous research do not provide an opportunity to analyze lower order components of affective states, like appraisals. Second, one of the main methods for inducing affect in participants has been the use of pictures. This approach has several methodological limitations, such as finding images that differ in valence and arousal but share the same luminosity. This study aims to address both these issues – using reliable stimuli and taking a closer look at the appraisal processes underlying affective states. To accomplish this, a novel paradigm was developed enabling pupil size measurements in the monetary incentive delay task (MID) (Knutson, Westdorp, Kaiser, & Hommer, 2000). Perceptually similar stimuli (Figure 1B) were associated with different events in three types of trials: gain, loss, neutral. To facilitate the learning process chocolate was used as reinforcement. The use of chocolate is justified by the idea that food-paired cues can increase motivation to obtain and consume food even when the participant is satiated (Colagiuri & Lovibond, 2015). Thus using food as an incentive can increase the relevance of the task to the participants.

This approach is designed to test three main hypotheses. First, the general hypothesis that pupil dilation differs in goal-relevant states compared to neutral states. If that is the case then the appraisal-based affective elicitation technique was successful in producing pupil dilation

Next, to investigate whether pupil dilation depends on availability of wins vs losses (i.e., goal type). This question can be answered by comparing the influence of win-related states and loss-related states on pupil dilation.

Lastly, whether pupil dilation depends on goal conduciveness vs goal obstructiveness of obtained outcomes (i.e., goal congruence). Pupil dilation during not winning (obstructed approach) and losing (obstructed approach) should be similar and pupil dilation during not losing (conduced avoidance) and winning (conduced approach) should also be similar, but dilation during conduced situations vs obstructed situation should be different.

Method

Participants

Forty seven participants (age: *M* = 22.62, *SD* = 4.45; 42 female) were recruited via social media (Facebook) and university email lists. All participants signed an informed consent form prior to the experiment. The study used two external incentives: chocolate and a chance to win a 50 euro gift card for Tartu Kaubamaja. Each participant received 100 or 110 grams of chocolate at the end of the experiment and at the end of the whole study one randomly chosen participant received the gift card. All participants had normal or corrected to normal vision.

Three participants were excluded from the sample due to pupil measurement problems caused by glasses. Interpolation of pupil data and trackloss analysis were conducted on the remaining participants. Three additional participants were removed due to insufficient data, as more than 60% of their recorded data was deemed unusable (see *Pupil data collection* for details). The primary analysis included data from 41 participants (age: *M* = 22.71, *SD* = 4.64; 38 female).

Procedure

The experiment was conducted in a dimly lit room. The researcher stayed in the room for the duration of the whole experiment in order to change experimental tasks and to give instructions at the beginning of each part of the experiment.

The whole experiment lasted approximately one hour. The experiment consisted of 5 parts, the order of the parts was as follows: subjective assessment of stimuli, implicit association test (IAT) to measure reaction times for stimuli, a game-like reward and loss task (MID), subjective measures of stimuli, implicit association test for the same stimuli. Reaction times gathered during the IAT are left out of the thesis due to the focus of the current research question. Since the MID task in itself was quite short, it proved convenient to use the study to collect data for two research questions. For the sake of clarity we left IAT out of experiment description.

The procedure started with a stimulus assessment task, participants were asked to give ratings to the stimuli used in the experiment on two dimensions: valence and arousal. Each stimulus was presented for 2 seconds and after each stimulus presentation an affect grid with the aforementioned dimensions was used to acquire ratings. Each stimulus was presented two times, the order was randomized. The next part was the MID task with concurrent eye tracking. The participants learned contingencies between the cues and loss-related MID events (*“you may lose”, “you lost”, “you did not lose”*), win-related MID events (*“you may win”, “you won”, “you did not win”*), neutral MID events (*“nothing happens”*, *“nothing happened”*) during the experiment. Text cues for the stimuli were provided in each trial. To make pupil measurement more reliable the text cues and stimuli were presented separately (Figure 1). Participants completed five training trials to get acquainted with the trial structure.

The MID task consisted of four blocks, each had 20 trials. In total the participants completed 80 MID trials. The blocks did not differ in terms of trial presentation the order of trials was randomized during the whole task. At the beginning of the task and after each block ratings of fatigue, chocolate craving, as well as valence and arousal of present mood were collected. The experiment contained control questions in relation to the preceding post-condition cue (“*did you just win/lose or not?*”). The questions were presented at the end of randomly selected trials, in total six control questions were used during the whole experiment. After the right answer was provided the experiment continued.

After the MID task participants repeated the first part of the experiment – stimulus assessment task. One minor difference was that each participant also completed a small task which required them to associate each stimulus with the text cue.

The experimental procedure was identical for all participants, only the association between MID event and the gap position were chosen randomly for each participant from four possible options.

Tasks

Stimulus Assessment. Self-report measures for the stimuli – Landolt circles used in the MID task – were taken before and after the MID task. The participants were asked to rate the circles in an affective grid consisting of two dimensions: valence and arousal. The second time the ratings were taken (after the MID task) control questions were added for each stimuli. Participants had to select the visual text cue used in the experiment for each stimulus.

Monetary Incentive Delay Task (MID). Gaze data and pupil size were measured only in this part of the experiment. For this purpose a different monitor (21"; ViewSonic PF817; 1024 x 768 px; 65 cm viewing distance) was used which was connected to the Eyelink software. In this task incentives were used to associate stimuli (Landolt circles) with different events (pre-conditions: *"you may win", "you may lose", "nothing happens";* post-conditions: *"you won”, “you didn’t win"*, *"you lost"*, *"you didn’t lose"*, *"nothing happened"*). The primary incentive was chocolate, participants could win or lose chocolate, they received the amount gained at the end of the experiment. The win and loss percentage was fixed –

every participant won in whole 90-110 grams of chocolate. The incentive delay task consisted of 80 trials. The trials were divided into four identical blocks. After each block participants were shown their overall score (how much chocolate they had won thus far) and ratings for mood and chocolate craving were recorded.

The trial (Figure 1A) structure was designed to facilitate pupil data collection. Each trial begun with a fixation cross being presented at the center of the screen (2 s) which was followed by a pre-goal cue (2 s). Participants then had to choose between two squares presented in the middle of the screen, one above the center point of the screen and the other below the center point. The participant was told that one of the squares was linked to the goal-obstruct condition (i.e. win or loss does not happen) and the other square was linked to the goal-conduce condition (i.e. win or loss does happen). The response was not timed. After selecting one of the squares the pre-goal stimulus (2 s) and the post-goal stimulus (2 s) were presented in conjunction. At the end of the trial the outcome was presented also in text form. The next trial begun when the participants pressed a mouse button. The stimulus to measure pupil size was presented in the middle of the screen.

After each trial participants saw a text cue of the outcome ("*you lost … grams", "you didn't lose*") and on every sixth trial also the amount of chocolate acquired thus far. The amount won at single trial was fixed, randomly chosen integer between 0 and 2 was in a reward trial added to a base of 15 grams and for a loss trial subtracted from the base. This function assured that participants finish the task with roughly 100 g. At the end of the experiment participants received the amount of chocolate that they acquired during the experiment in chocolate bars (100g and 10g).

Apparatus and Stimuli

The experiment was visually presented with Psychtoolbox (Brainard, 1997) and MATLAB 2015a *(Mathworks, Inc.)*, the script included Eyelink toolbox extensions (Cornelissen et al., 2002).

Stimuli in the MID task were black (lum = 4 cd/m²) Landolt circles (Figure 1B) presented on a homogeneous gray background (lum = 49 cd/m²). All circles had same size, diameter of 5.4 cm (4.9° × 4.9°). Neutral cues were for all participants the same - full circles. Cues associated with reward and loss conditions had an equally sized gap centered at one of six directions (0, 45, 135, 180, 225, 315 degrees). The experiment was counterbalanced, the pairings between the MID events and gap positions varied among four possibilities. Pre event

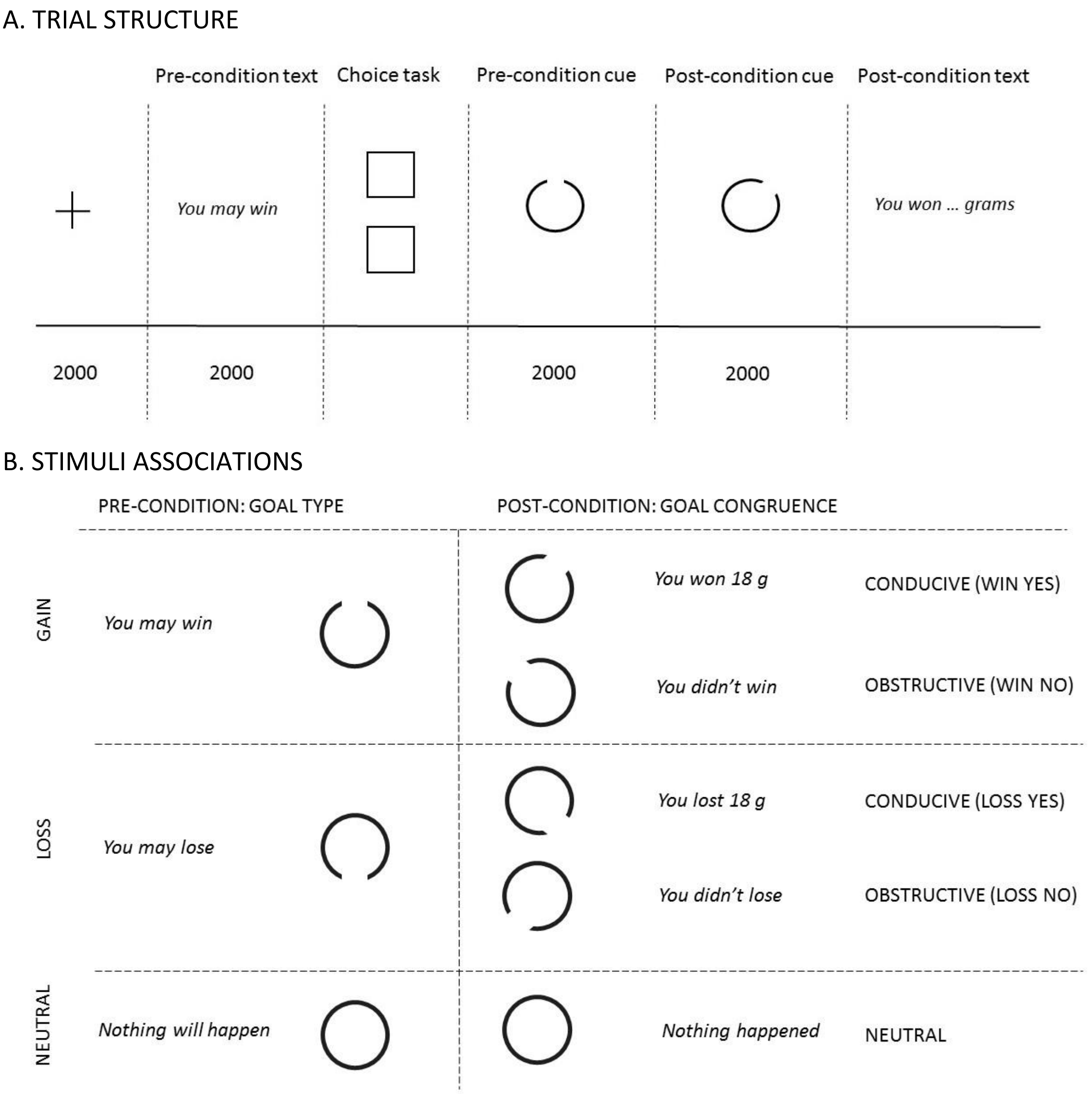

Figure 1. Overview of the experiment. The experiment was run on a gray background A. Trial structure. Four segments were 2000 ms long, the other two segments were not timed. B. Stimuli associations. The experiment was counterbalanced. The meaning of the stimuli was switched within conditions. Only the circle indicating the neutral condition remained the same for all the participants.

cues (Figure 1B) varied among themselves. Post event cues were related to the pre event cues, so that the direction of the gap (upwards, downwards) was the same for one type of events.

For subjective measures two scales were used: a one-dimensional visual analog scale and a two-dimensional affect grid scale. Present fatigue and chocolate craving were measured on the one-dimensional analog scale ranging from 0 to 100 with labels relating to the questions. Mood and stimulus affective ratings were collected with the affect grid scale (Russell, Weiss, & Mendelsohn, 1989). The grid consisted of 10 horizontal and 20 vertical unlabeled gridlines. The endpoints for the vertical arousal axes were labeled "weak" and "strong". The endpoints for the horizontal valence axes were "unpleasant" and "pleasant".

Participants used mouse buttons to give answers to the subjective measures and to make a choice in the MID task. In the MID task the participants hold the mouse so that the left button was used to select the box above the center line and the right mouse button to select the bottom one.

Pupil Data Collection

Pupil data during the MID task were collected using Eyelink 1000 (SR Research Ltd., Missisauga, ON, Canada). Calibration and validation of gaze direction were conducted at the beginning of the MID task. Pupillometry data were preprocessed with Eyelink Data Viewer (SR Research Ltd., Missisauga, ON, Canada) and analyzed in R (R Core Team, 2014) and RStudio (RStudio Team, 2015) software with functions provided by R package eyetrackingR (Dink & Ferguson, 2015).

Eye tracking was used for the right eye with a sampling rate of 500 Hz. Blinks were detected with the manufacturer’s standard algorithm. Area of interest – stimuli size plus 20% of the size to each direction - was used to filter the data. Pupil dilation during blinks was interpolated. Single trials with more than 40% missing pupil data were discarded before interpolation. Participants with more than 60% pupil data missing after the interpolation were also discarded.

For examining transient (trial-related) effects, we subtracted a baseline period from all trials. First we subtracted pupil activity measured at the presentation of the fixation cross. For post-conditions we also used an additional baseline, we subtracted pupil activity measured at the presentation of pre-conditions.

Data Analysis

The central analysis is repeated measures analysis of variance (rmANOVA). Effect sizes were reported with generalized eta squared statistic (Bakeman, 2005). Greenhouse-Geisser or Huynh-Feldt (if GG epsilon > .75) p-values were reported when the assumptions of sphericity was violated (Maulchy test $p < .05$). R package ez (Lawrence, 2013) was used for rmANOVA analysis. For post hoc test pairwise comparisons with t-tests were conducted, Benjamin and Hochberg (1995) method was used to correct p-values. The correction reduces familywise Type I error risk.

Results

Manipulation Checks

First we did a manipulation check for the first stimulus assessment task, conducted before the MID task. We expected that the stimuli should have no affective meaning beforehand. To check this hypothesis we performed a rmANOVA with 7–level factor (*win pre, win yes, win no, loss pre, loss no, loss yes, ntr*) for the valence and arousal ratings separately.

There was a significant effect of stimuli on the valence rating means, $F(6, 276) = 19.770$, $p = .000$, $\eta_G^2 = .155$. For post hoc analysis we did pairwise t-tests. Only the full circle (in our experiment – the neutral condition) differed from other stimuli ($p < .000$).

There was a significant effect of stimuli on the arousal rating means, $F(6, 276) = 4.288$, $p = .010$, $\eta_G^2 = .031$. For post hoc analysis we did pairwise t-tests. There was a significant difference between two pairs of stimuli: full circle differed from circle with a gap up-left ($p = .006$) and full circle differed also from circle with a gap up-right ($p = .004$).

We expected that during the experiment participants associate the stimuli with affective values according to the events. To test this expectation we investigated the change in self-reported values of stimuli between the ratings given at the end of the experiment and ratings given at the beginning of the experiment.

The second manipulation check was conducted by analyzing the difference between the assessments participants gave at the end and at the beginning of the experiment. We subtracted the first assessment ratings from the second ratings and did a rmANOVA with 7 –level factor (*win pre, win yes, win no, loss pre, loss no, loss yes, ntr*). Figure 2 illustrates the change in assessment due to the experiment.

There was a significant effect of stimuli on the valence rating means, $F(6, 276) = 23.210$, $p = .000$, $\eta_G^2 = 0.272$. For post hoc analysis we did pairwise t-tests (Table 1).

Table 1
P-values for mean valence difference in assessments

	loss no	pre loss	loss yes	ntr	win no	pre win
pre loss	.000					
loss yes	.000	.000				
ntr	.000	.003	.529			
win no	.000	.047	.000	.000		
pre win	.047	.000	.000	.000	.003	
win yes	.000	.000	.000	.000	.000	.000

Notes: Benjamin and Hochberg correction.

There was a significant effect of stimuli on the arousal rating means, $F(6, 276)$ = 12.840, p = .000, η_G^2 = .103. For post hoc analysis we did pairwise t-tests (Table 2).

Table 2
P-values for mean arousal difference in assessments

	loss no	pre loss	loss yes	ntr	win no	pre win
pre loss	.347					
loss yes	.000	.000				
ntr	.000	.000	.000			
win no	.916	.310	.000	.000		
pre win	.878	.252	.002	.000	.916	
win yes	.000	.000	.777	.000	.000	.000

Notes: Benjamin and Hochberg correction.

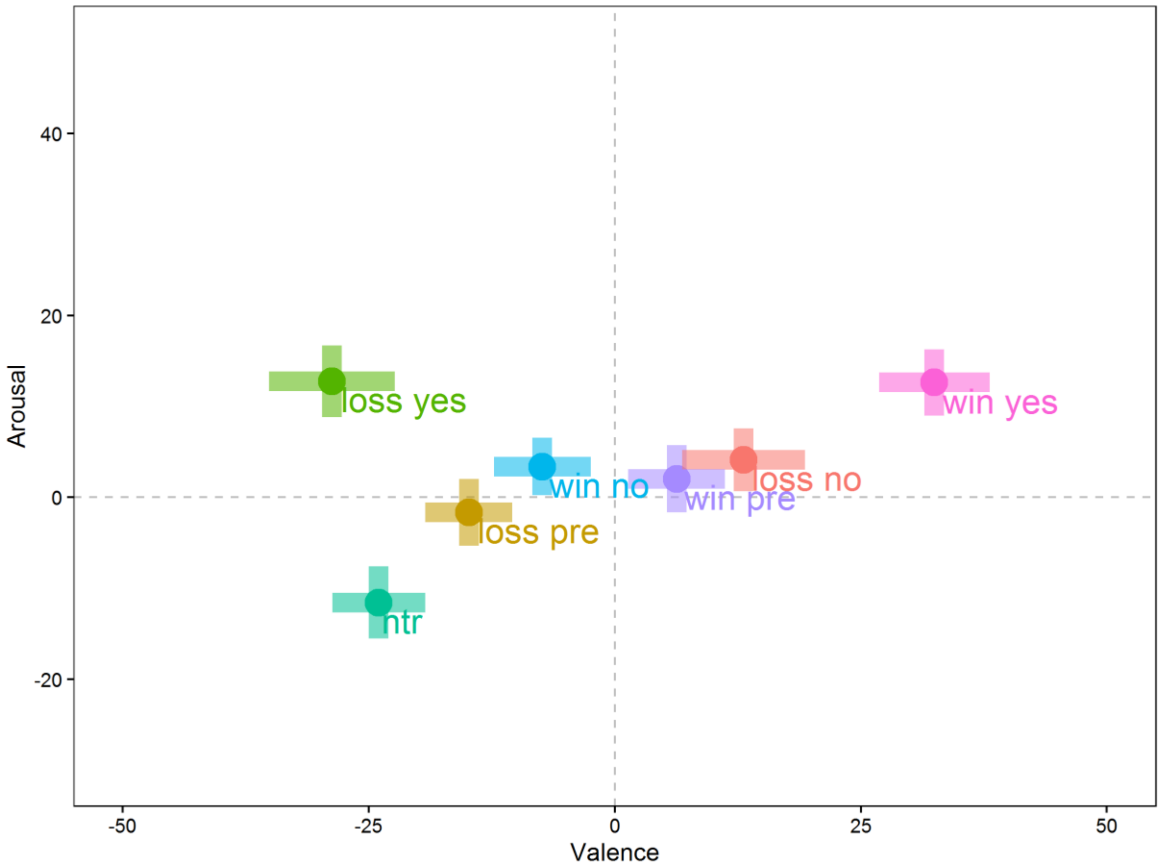

Figure 2. Changes in stimulus assessment due to affective conditioning. The plot shows the shift in stimulus assessment, for example stimuli that are on the right of the vertical dashed line were assessed more positively after the experiment than before the experiment.

Finally we checked the difference of how different stimuli were recalled at the end of the experiment. The mean recall percent for all the participants was 76.31 % (range 14.29 to 100%). Seven participants recalled less than 50% of the stimuli. When we removed the seven participants that had poor recall of the stimuli the mean recall percent of the remaining 34 participants was 89.18% (range 57.14 to 100 %). In our main analysis we use data from all the participants, but we run the analysis also with only the participants who had a recall percent of over 50 %. The results of the statistical analysis did not show significant changes. The best recall percent was for the full circle (neutral stimuli for all the participants), 97.87 %. The recall percent for other stimuli ranged from 59.57 to 76.60 %. A Chi-square test of independence was calculated comparing the frequency of different stimulus recall. No significant difference was found $\chi^2(6, N = 94) = 10.376$, $p = .110$.

Main Analysis

Pre-Condition Effects. We made a separate analysis for the pre-goal trial conditions. Pupil data were measured after the notification of the trial condition, during the presentation of the stimulus associated with a specific condition. There was a significant effect of pre-goal conditions on the pupil size means, $F(2, 80) = 25.945$, $p = .000$, $\eta_G^2 = .187$. Figure 3 shows that in pre win condition the mean pupil size during the stimuli presentation period was higher than in the other two conditions. In neutral conditions the pupil showed less reaction to the stimuli than in win and loss conditions.

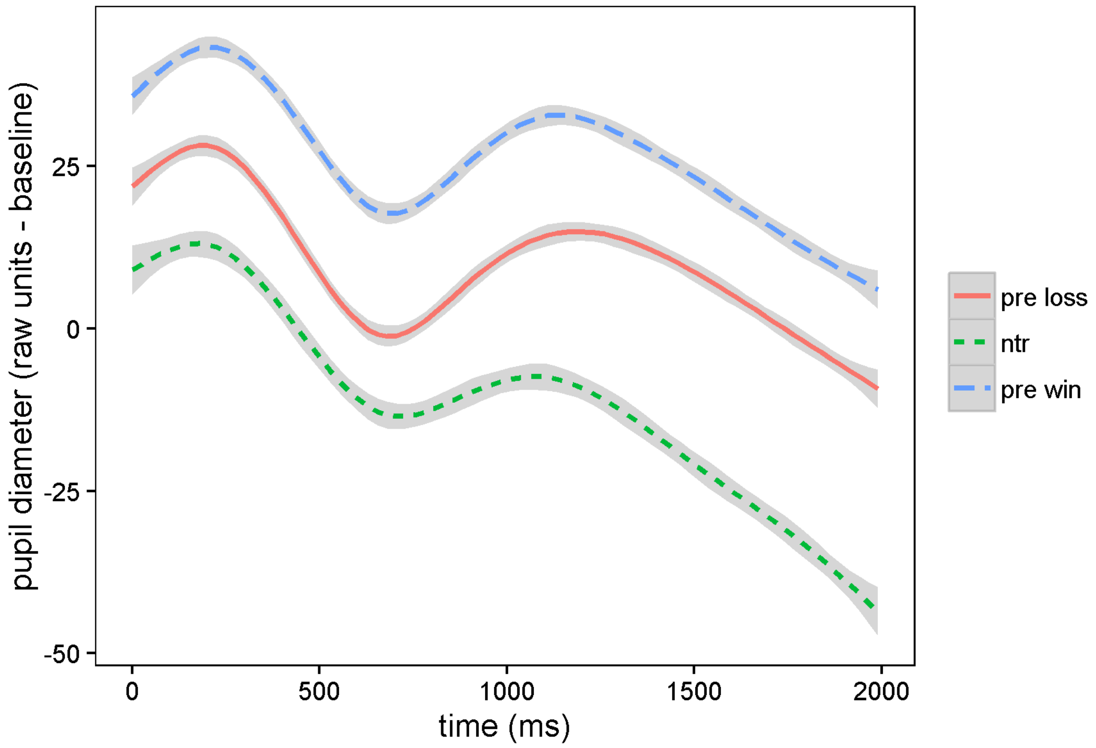

Figure 3. Difference in pupil size during pre-conditions.
Notes. pre loss - “you may lose”; ntr – “nothing will happen”; pre win – “you may win”.

Paired samples t-tests were used to make post hoc comparisons between the pre-goal trial conditions, all the conditions differed significantly from each other (p < 002).

Post-Condition Effects. We also made a separate analysis for the post-goal conditions. Measures for the post-goal conditions were taken exactly after the pre-goal symbol, the specific post-goal symbol was presented to the participant for 2 seconds. After the symbol the text with the meaning of the symbol was presented. Pre-condition pupil mean was used as baseline. There was a significant effect of post-goal conditions on the pupil size means, $F(4, 160) = 14.846$, $p = .000$, $\eta_G^2 = .187$. Figure 4 shows that significant events differ from the neutral condition. Also we see that the conditions where subjects won and did not win differ from each other.

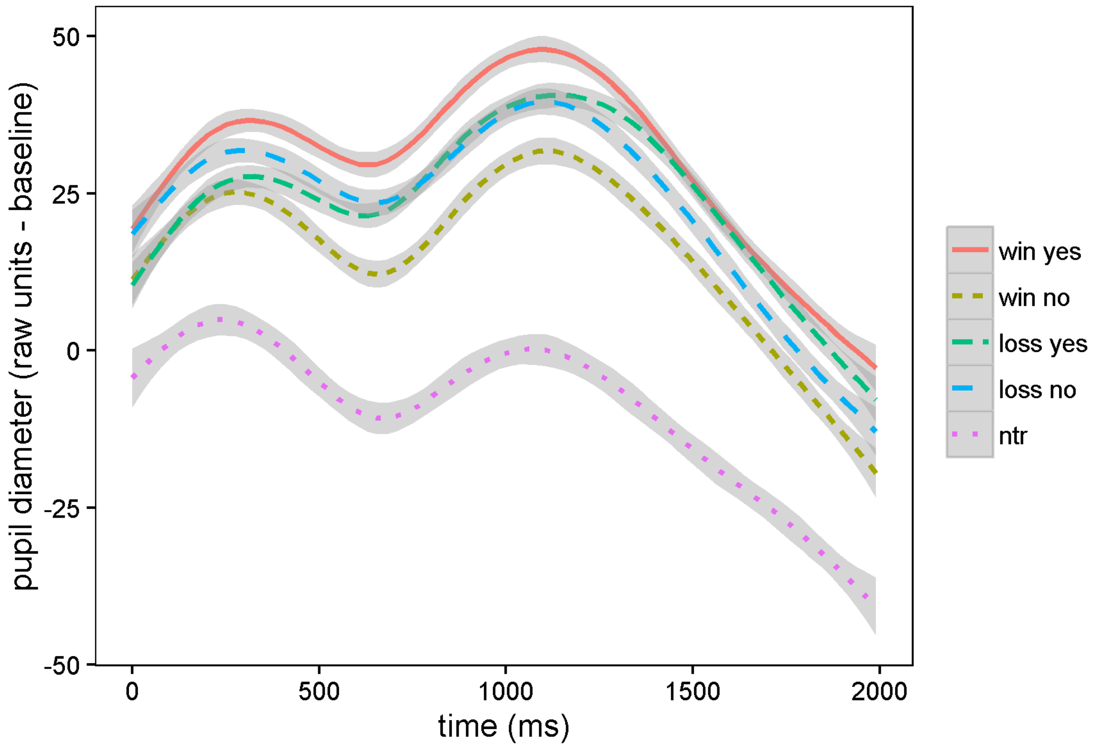

Figure 4. Differences in pupil size during post-conditions.
Notes. win yes – „you won .. grams“, win no – „you didn't win“; loss yes – „you lost … grams“; loss no „you didn't lose“; ntr – „nothing happened“.

Paired samples t-test were used to make post hoc comparisons between the post-goal conditions (Table 3).

Table 3
P-values for mean post-condition differences

	win yes	win no	loss yes	loss no
win no	.008			
loss yes	.159	.158		
loss no	.210	.210	.797	
ntr	.000	.003	.000	.000

Notes: Benjamin and Hochberg correction.

Additional Analysis

For analyzing the effect of valence and arousal on pupil size we conducted a correlation analysis between the change in stimulus ratings and pupil size.

Valence ratings to the stimuli and pupil size showed a significant correlation, r = .186, p < .000, one tailed. Arousal ratings and pupil size were also significantly correlated, r = .269, p < .000, one tailed. Higher valence and higher arousal ratings were associated with more dilated pupil size (Figure 5).

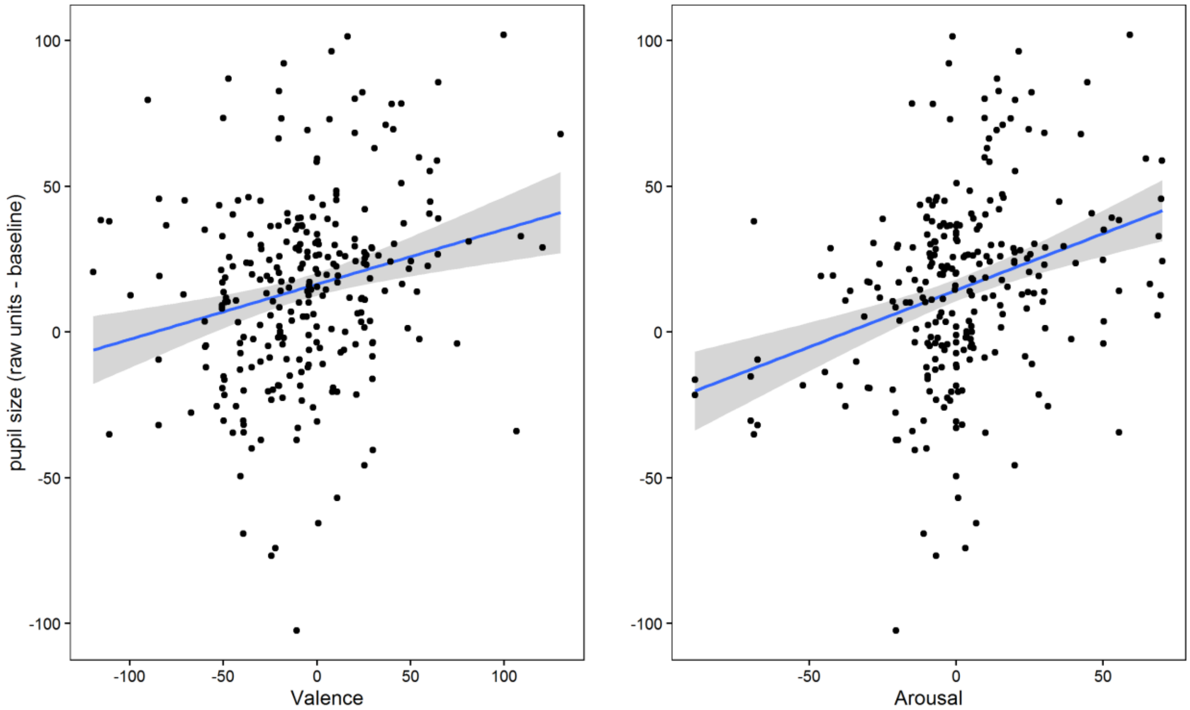

Figure 4. Correlation between pupil size and subjective valence and arousal ratings for stimuli.

Discussion

This thesis took a closer look at how different appraisal dimensions influence pupillary reactivity. I formulated three hypotheses about the effects of appraisals on pupillary movements. Pupillary reactivity differs due to a) goal-relevance (relevant events differ from neutral events); b) goal type (wins and losses can show a different pattern) c) goal congruence (obstructed vs conduced conditions introduce changes to pupillary movements). I will now discuss the results of these questions in more detail to show how they tie into the appraisal theory.

As predicted, the results showed that goal relevance had an effect on pupillary reactivity, neutral conditions differed significantly from all other conditions. Goal type also had an effect on pupillary reactivity. To a degree goal conduciveness too showed the pattern predicted, as pupil reactivity changed, but only in approach conditions (conditions "*you won*" and "*you did not win*" differed significantly). The underlying pattern can be described as follows: pupil dilation increased more in the reward and conduced-approach conditions compared to loss and avoidance motivated conditions.

Manipulations checks showed clear results in favor of the method used. The effect of goal relevance was evident in both pre-condition and post-condition trials, pupil size during the neutral cues differed from other trials significantly. This is an important finding because it demonstrates that the difference in conditions was affective in nature. The effectiveness of the method is also evident from the behavioral data. Although at the start of the experiment the participants assessed the full circle (the neutral cue) as more positive and more arousing than other stimuli. The starting point therefore was not the same as in Kliegl, Watarin, Huckauf's (2014) study where no difference was present at the beginning of the experiment. We expected that affective conditioning in the MID task would introduce changes in stimulus evaluations dependent on their associations with events. As expected the values attributed to the cues during the experiment followed a logical path (Figure 2). Changes in values were contingent on the MID task: valence and arousal ratings decreased for the neutral cue, cues associated with goal relevant events (especially conduced approach and conduced avoidance) showed a clear shift on both assessed dimensions. Statistical analysis of the differences in stimulus ratings added another layer of proof to the effectiveness of the method used. Before the MID task the gain-related and loss-related cues did not differ statistically from each other. After the task there were several differences among the cues which demonstrates the successfulness of affective conditioning during the experiment.

To test the hypothesis that goal type modulates pupil dilation I analyzed if pupil size depends on the availability of wins and losses. During the pre-condition participants knew the goal of the trial, but did not know the outcome of the trial. All three trial (*"you may win", "you may lose", "nothing happens"*) means differed from each other. A significant difference between wins and losses in pupil size adds a second confirmation to the effect of appraisal given to the stimuli. It seems that the pre-condition *"you may win"* was appraisal wise the most important one as was evident from the fact that pupil dilation was significantly larger in this condition compared to the other two conditions (Figure 3). In accordance with the expectation also the pre-condition *"you may lose"* showed an influence on pupil size compared to the neutral condition *"nothing happens*". From the appraisal theory perspective this can be explained by the importance of the situation. Participants may have found reward conditions more goal relevant. What matters to the person's perception of the situation is of central importance in appraisal theory (Ellsworth, 2013). When the situation is evaluated as more important the more intensive the resulting affective state. In this experiment the reward conditions might have been more important in the aspect of the whole score (the task was built understandably so that no one could end with a negative score). Appraisal theory postulates that appraisals are fundamental components of affective states, affective states can arise from the appraisals given to a situation (Gross & Barrett, 2011; Elsworth & Scherer, 2003, Moors, Ellsworth, Scherer, & Frijda, 2013). The results of goal type from the experiment conducted can be interpreted in the same line: goal type produced the affective state, which includes increased valence and arousal. The reward situations were more important for the participants which is why the pupil dilated more in that condition.

We also tested whether goal congruence modulates pupil dilation. To test this hypothesis we compared pupil dilation during not winning (obstructed approach) vs losing (obstructed approach) and not losing (conduce avoidance) vs winning (conduce approach). The only significant difference was found between not winning (obstructed approach) and winning (conduce approach). This result gives further proof to the argument that reward conditions were more important to the participants. The goal-congruence appraisal changed the affective state that started in the pre-condition. The change was present only in the reward condition. We may conclude that pupil dilation indeed shows some reactivity to goal-congruence, but further studies are necessary to shed more light on the matter.

In a broader aspect we set out to find if there is an effect of appraisal dimensions on pupillary reactivity in addition to the arousal dimension. Previous research has given concrete results that the arousal dimension affects pupil responses (Bradley, Miccoli, Escrig & Kang

2008). This thesis is not trying to convince the reader that arousal does not play any part in the process. Instead, this experiment tried to disentangle the effects of appraisal dimensions from those of arousal and ask whether we can see how the dimensions alone affect pupil size. The weak positive correlations of valence and arousal ratings with pupil size show that both dimensions explain some part of the variance in pupillary reactivity (Figure 5). We see that although there is a significant correlation between arousal and pupil size, the correlation is quite weak (r = .269). It is interesting to note that the valence dimension also showed a weak correlation (r = .186). This result was expected because the effect of appraisal dimensions should produce subjective emotional experience that can be described by these two dimensions. The correlations with subjective valence and arousal ratings show that appraisals generated subjective experience that echoed on those dimensions.

This experiment can also be linked together with research that has been done in the context of motivational value and vision. It has been shown that participants show better and faster detection of stimuli that have been associated with rewards compared to neutral stimuli (Vuilleumier, 2015). It is interesting to note that learned reward associations have also been shown to influence eye movements; when the same stimulus is associated with high reward it captures the eye much faster as opposed to when it is associated with low reward (Theeuwes, Belopolsky, 2012). This experiment demonstrated that also the pupil is sensitive to reward conditions. Important situations usually have some degree of affective value to the person. From an evolutionary perspective it is understandable that the eye is more attuned to search for emotionally appraised stimuli, it has value to the person and his/her survival success in the environment. The pupillary reactivity to affective states may be caused by the same type of mechanism. The brain channels more energy into processing emotional stimuli compared to neutral stimuli, pupillary response to affective stimuli shows that the brain is assessing the stimuli as more important.

Conclusions

The present findings go beyond previous explanations of affective influences on pupil responses. Previous research has focused mainly on the arousal and valence aspect of emotions. The results of this study demonstrated that appraisal dimensions such as goal relevance, goal type and goal congruence have also an effect on pupillary reactions. Future research into affective influences of pupil responses should focus on differentiating the effect of affective components even more. The idea to use affective conditioning together with simplistic stimuli seems to be an effective approach for studying appraisals.

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