Interoception and conscious access

One's Stomach isn’t bigger than one's eye’s: the sensation of hunger does not boost images of food into visual awareness.

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Abstract

The sensation of hunger is an ecologically important aspect of life and so far no research has assessed how hunger could play a role in selecting the content of visual awareness. A healthy group of observers is tested using the breaking Continuous Flash Suppression task. This task allows measuring the time it takes for interocularly suppressed stimuli to gain perceptual dominance. Here, the sensation of hunger is manipulated to assess the role it has on interocular competition between different stimulus categories (i.e. Food, Animal, Object and Transport). Although interoceptive information such as hunger is highly ecologically relevant, the results provided no evidence that hunger has an effect on perception. Additionally, the method used within this experiment is new to the field and might provide new insight for research into visual awareness. The present results are discussed in light of the locus at which interocular competition is resolved.

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Introduction

Lots of sensory or cognitive processes take place in the brain, yet we can consciously report or experience only some of them. To get a broader idea on how consciousness arises and why some information is selected over other information one must look at the functions of consciousness rather than the phenomenology (Cohen, Dennett, 2011). Here, the phenomenology is considered a hard problem of consciousness and can never be verified or falsified because, it is the product of cognitive functions that allow consciousness to be empirically studied. Research that focuses on the functions of consciousness could explain the role of consciousness and might explain why consciousness is present in our brain. Thus, one can form better theories of consciousness by studies focusing on the functions of consciousness.

One influential theory of consciousness is The Global Workspace theory (Baars, 1988; Dehaene, & Naccache, 2001). Here, various unconscious processes/modules are presented in a workspace to compete or make coalitions to set the content of consciousness. Some of these modules arise from the sensory input, such as visual, auditory, tactile, olfactory or taste systems. Other modules come from within the observer, such as emotion, sense of self, or interoception. Awareness is the subjective experience of an individual that arises from these modalities. Thus, measuring someone’s ability to explicitly report subjective percepts operationalizes visual awareness. Therefore, a function of consciousness can be explained by looking at visual awareness and how this interacts with awareness arising from other modalities.

Some stimuli presented outside our visual awareness have the potency to influence our behavior (Klotz & Neumann, 1999; Neumann & Klotz, 1994; Eimer & Schlaghecken, 1998). A number of studies examined the effect of low-level perceptual features of a stimulus, such as orientation, spatial frequency, color and linear motion (for a review, see Lin & He, 2009), and how this affects perceptual competition during rivalry. They found that changes in low-level features presented during suppression did not alter the interocular competition of two simultaneously presented stimuli (Blake & Fox, 1974; Lehmkuhle & Fox, 1975). Here, changes made to the physical properties or low-level features (e.g. color, orientation, spatial frequency and location) of the stimulus are examined to postulate its influence on the interocular competition during binocular rivalry. High-level features (e.g. semantic information, emotional information) are not examined nor important because, if the suppression mechanism is unresponsive to the fundamentals of low-level features, there is no reason to believe that it would be responsive to complex patterns derived from them (Blake & Fox, 1974). In general, these studies lead to the more traditional view that unseen stimuli have the potency to influence behavior, but mostly do so in an acquired, automatic manner that is insensitive to volitional control.

Nevertheless, a growing number of studies focus on high-level features or processes and how these rely on visual awareness. From this research one can postulate the function of visual awareness where they see it as a necessary condition for decision making (Van Gaal, Lange & Cohen, 2012), error identification and correction (Posner, 1998) and planning (Crick & Koch, 2003). Here, awareness is not required for low-level perceptual binding but is necessary for rapidly joining together perceptual and conceptual information from diverse modules to create a unified and coherent scene or idea (Tononi & Edelman, 1998). According to these views mentioned above, awareness can be described as the ability to establish specific relationships between representational items, which will create the formation of a structured mental representation (Engel, Fries, Konig, Brecht, & Singer, 1999). Marcel (1983) states that awareness is a constructive function that is indispensable for perceiving and comprehending the meaning of scenes. Thus, a conceptual relationship between objects or concepts is not established under unconscious perception.

However, a recent study of Jiang, Costello & He (2007) suggests that high-level stimulus features can be processed without visual awareness. He showed participants stimuli of inverted and upright faces and found faster response times for upright faces compared to inverted faces, when these stimuli where masked under interocular suppression. Since upright and inverted faces consist of identical low-level features, the difference in RT was interpreted as reflecting differences in preserved higher-level processing under interocular suppression. Other findings suggests that high-level processes like task relevance and goal directed control settings could influence the way unseen stimuli influence behavior (Ansorge & Heumann, 2006; Ansorge & Neumann, 2005; Jaskowski, Skalska, & Verleger, 2003; Kiefer & Martens, 2010; Schlaghecken & Eimer, 2004). Next, Mudrik, Breska, Lamy, and Deouell (2011) focused on conceptual integration between objects and how this relates to visual awareness. They found that a conceptual integration between objects was established in the absence of visual awareness. Furthermore, neuroimaging studies showed evidence that high-level information like object category information from the suppressed stimulus is being processed in cortical and subcortical structures (Williams, Morris, McGlone, Abbot, & Schultz, 2004; Fang & He, 2005). A study in unilateral neglect patients suggests that patients with neglect are able to process stimuli presented to the neglected field to a categorical level of representation, even when they do not report seeing the stimulus in the affected field (Berti & Rizzolatti, 1992). Even with cortical blindness (hemianopia) emotional stimuli are still processed to the extent that behavior is altered, without giving rise to awareness (Tamietto, Castelli, Vighetti, Perozzo, Geminiani, & Weiskrantz, 2009). Thus, research from different fields in neuropsychology reveals high-level processing of stimulus information while awareness of the stimulus is not yet established.

The relevance of a stimulus is important to understand our actions and behavior. Ansorge, Horstmann & Worschech (2010) found that masked color singletons captured attention, and thereby awareness, when they matched the participants' task set (e.g., "look for the green target") but failed to capture (stimulus-driven) attention when they were task irrelevant. This suggests that even very early visual processing (i.e., preceding visual awareness) is dependent on the participants' goal directed intentions. In line with this research Gayet, Stigchel & Paffen (2014) presented participants arrow cues rendered invisible by interocular suppression. When intermixed visible arrow cues were highly predictive with the subsequent target location (i.e. 80% congruent) it created a facilitatory cueing effect. However, no subliminal cueing effect was present when the visible cues were non-predictive (i.e. 50 % congruent), Second, they demonstrated that the intrinsic relevance of invisible cues (either 50% or 100% congruent) had no effect on the use of visible cues. They concluded that conscious perception is required to make statistical conclusions about the relevance of symbolic cues. Once this statistical information is extracted consciously, it will affect non-conscious processing in such a way that it fits the current context. So, high-level information can be extracted from visual stimuli in the absence of visual awareness. However, the creation of intentions or rules for behavior has to arise consciously (prior to the non-conscious processing).

These studies show that task relevance of the stimulus already effects visual processing before consciousness sets in. Ecological relevance is probably the pinnacle of relevance in any organism under selective pressure. Here, it could influence behavior before the organism becomes aware of it. Research is supporting this view for certain events, for instance, emotional face expressions where subjects' awareness of the angry faces was prevented by backward masking with a neutral face. A significant neural response was elicited in the right, but not left, amygdala to masked presentations of the conditioned angry face (Morris, Ohman, & Dolan, 1998; Whalen, Rauch, Etcoff, McInerney, Lee, & Jenike, 1998). Other research focused on snakes and spiders, which elicited a fear response when stimuli were presented without visual awareness (Ohman & Soares, 1994). A study of Jiang et al. (2006) showed that spatial attention could be modulated by sexually arousing stimuli (nude pictures of males and females) presented without visual awareness of the stimuli. This effect depended on both the gender and the sexual orientation of the participant. If the stimulus is of biological relevance for the participant it seems to attract spatial attention without visual awareness of the stimulus. So, a growing number of studies are suggesting that higher-level processes could influence visual awareness, and especially so when the stimuli presented are of high ecological relevance.

One recent paradigm, derived from binocular rivalry, that lends itself particularly well for measuring such prioritization in the competition for visual awareness is breaking Continuous Flash Suppression (b-CFS). Within the b-CFS research, breaking suppression durations are examined between different categories like upright vs. inverted faces (Jiang, Costello & He, 2007), familiarity vs. unfamiliarity words (Jiang, Costello & He, 2007), direct gaze vs. averted gaze (Stein, Senju, Peelen, & Sterzer, 2011), unnatural vs. natural scene content (Mudrik, Breska, Lamy, & Deouell, 2011). Most research focused on stimulus-driven changes that influence behavior without visual awareness. Here, the content of the presented stimulus is manipulated to investigate its result. These studies focused on how differences in the visual modality could have a priority for visual awareness. Some research also focused on manipulating non-visual information to investigate the effect it has on visual awareness like auditory information (McDonald, Teder-Salejarvi & Hillyard, 2000) olfactory information (Zhou, Jiang, He, & Chen, 2010b), and proprioceptive information (Salomon, Lim, Herbelin, Hesselmann & Blanke, 2013). This latter study investigated the potency of information from the proprioceptive modality in affecting visual awareness. They found that visual stimuli that are congruent with the current body position gain more rapid access to visual awareness. Thus, it seems that not only changes in visual information but also information from different modalities could have an influence on visual awareness.

Using a b-CFS task, the present study investigates whether ecologically relevant interoceptive information (i.e. the sensation of hunger) influences someone's perception. Hunger is biologically associated with the hormones ghrelin and insulin. High blood plasma levels of ghrelin and leptin and low blood plasma levels of insulin induce a hunger sensation. After a period of 5 hours (300 minutes) an increase of the hormone levels ghrelin, leptin and a decrease of insulin in blood plasma occurs and give the participant the sensation of hunger (Cummings, Frayo, Marmonier, Aubert & Chapelot, 2004). Being hungry is of high relevance for any organism in such, that it is a helpful tool for survival. Here, hungry participants are presented with stimuli of food, animal, object, and transport and have to indicate when they see a stimulus breaking through the color masks (Mondrians) either on the right or left side of fixation. The same group of participants is tested a second time, with the difference that participants had eaten before testing. So far no research has focused on the interoceptive modality and how interoceptive information can influence perception without visual awareness. It would make sense in an evolutionary way that relevant information (images of food when hungry) is prioritized within the visual system, thus breaching the threshold of awareness at an earlier point in time compared to non-relevant information (images of animal, object and transport). The research question we focus on is: Do food stimuli have a precedency in visual awareness compared to non-food stimuli when observers are hungry? Here, we expect faster response times (RT) for food stimuli compared to non-food stimuli. Moreover, is this effect still there when the hunger group is compared with a not-hunger group? Here, we expect that the prioritization of food stimuli over non-food stimuli is greater in the hunger condition compared to the not-hunger condition. Does interoceptive information have an influence on the content of visual awareness such that this information is prioritized over information arising from other cognitive modalities? The present study will examine and discuss these questions.

In order to block the presented stimuli from visual awareness, we used Continuous Flash Suppression (CFS;) Tsuchiya & Koch, 2005). With this method, distinct color images (Mondrians) presented to one eye at 10Hz reliably suppress stimuli presented to the other eye for a relatively long duration. The time it takes for the suppressed stimuli to break suppression and reach visual awareness provides a measure of prioritization for conscious access of that particular stimulus (the b-CFS method). The effectiveness of suppression differs between stimuli even though the stimuli have the same amount of low-level information. High-level information (semantic information) differs between the stimuli, such that each stimulus belongs to one of the four categories (transportation, objects, food and objects). Therefore, this higher-level information must be processed during the suppression of the stimulus. If not, one stimulus could not break through suppression faster than the other stimulus.

In the present study, we used this method to suppress awareness of two concurrent stimuli appearing on the right or left of fixation. Both stimuli are selected from 4 different categories (food, animal, object and transport). We instructed a group of participants not to eat or drink sugar-containing beverages for 5 hours prior the experiment (hunger condition) and tested them a couple days later for a second time with the instructions to eat something before the experiment was conducted (not-hunger condition). In the experiment, participants were required to respond as soon as they detected which side (left or right hemifield) the stimulus appeared. We compared the response times (RT) between the different categories in both the hunger and not-hunger condition. Moreover, we compared the RT's of each category between the hunger and not-hunger condition. Crucially, at the end of each trial, we asked participants to indicate which category the reported or not-reported stimulus belongs to. This way, we surely can say that just one stimulus was seen over the other. Additionally, we surely can say that the particular category is consciously perceived.

Methods

Participants

29 participants (12 male, 17 female, *M*= 24, *SD*= 2,38) were recruited from the University of Utrecht. Participants had normal or corrected-to-normal vision. All participants were tested for stereoscopic vision with the TNO test for stereoscopic vision (12th edition; Laméris Ootech b.v., 1972). They participated voluntarily or for course credits.

Apparatus

An Apple dual 2-GHz PowerPC G5, fitted with a linearized 22'' LaCie Electron blue IV CRT monitor (1024 x 768; 100Hz) was used in the experiment. Additionally, an Apple keyboard was used for response registration. The visual stimulation was presented dichoptically using a mirror stereoscope mounted on a chinrest, keeping the observer at an effective viewing distance of 57 cm. The experiment room was quiet and dark (except for the light of the monitor). The presentation of the stimuli and the response collection were managed using the Psych Toolbox 3 (Brainard, 1997; Pelli, 1997) in MATLAB R2010a (The Mathworks, Natick, MA).

Stimuli

The experiment contained five categories of stimuli (food, animal, object, transport and empty). An overview of the used stimuli in this experiment is provided in the appendix. The stimuli category “Food” consisted of 32 different stimuli related to food. The same was done with the stimulus categories “Animal”, “Object” and “Transport”. Additionally, an “Empty” category was included in which no stimulus was presented. All test stimuli were monochrome pictures that were taken from Internet (http://thenounproject.com). The stimuli were altered using Matlab R2010a. Stimulus polarity was reversed to fit the background color and contrast was reduced to provide longer suppression durations. For each category, the mean luminance was measured with a photometer and compared with each other. Paired sample t-tests showed no significant differences in limunance between the stimulus categories “Food”(M = 179.33, SD = 32.40), “Animal” (M = 182.26, SD = 28.40), “Object”(M = 179.52, SD = 35.42) and “Transport”(M = 181.18, SD = 23.40) with all $p > .70$.

The suppressors were Mondrians, random amalgams of partly overlapping rectangles of varying sizes and colors. During the experiment, a black background with a white rectangular frame (5.8° x 5.8°) surrounded the area presented to each eye such as, to facilitate binocular fusion of the images presented to both eyes.

Procedure

First, an informed consent was signed by the participant to agree on participating with the experiment. Second, the participant was tested for stereoscopic vision with the TNO test for stereoscopic vision (12th edition; Laméris Ootech b.v., 1972). Third, the chinrest and seat were put in the correct position. Before starting the experiment, the participant was instructed about the trials in the experiment and how to respond to them. When there were no further questions the experiment started with a practice block comprising of 8 trials. The actual experiment started when the practice block was performed correctly and the participant had no further questions. At the beginning of each trial a fixation cross and the white rectangular frame were presented (Figure 1). The participant was instructed to maintain fixation on this fixation cross throughout the experiment. Next, two sequences of Mondrians were presented at full contrast left and right of fixation to one of the participant's eyes, while the test scene was presented to the other eye. The test scene consisted of two stimuli right and left of fixation. Each of the stimuli belonged to a different category (food, animal, object, transport or empty). The contrast of the test scene was gradually ramped up from 0% to full contrast over a timespan of 1 second. After nine seconds the Mondrians decreased from full contrast to 0% contrast in 1 second, which resulted in a ten second duration for each trial. The test scene stayed at its full contrast during this time. The task lasted until a response was given or until the ten seconds had passed. The participant had to indicate as fast and accurately as possible whether a stimulus appeared on the left or right of fixation. Moreover, it was emphasized that it was not necessary at first hand to know the content off the picture. Responses were made on a keyboard.

After the participant completed the response a screen with an arrow and 4 pictures representing the 4 different stimulus categories appeared. The participant had to indicate which category the stimulus belongs to (visibility-check). This was done by pressing the keys Z, X, C and V corresponding to the four categories (food, animal, object and transport). Over half of the trials, the participant was asked to report the stimulus category that appeared through suppression (reported side). In the other half of the trials, the participant was asked to report the stimulus category that did not break through suppression (not-reported side). The participant was forced to make a (non-speeded) choice out of the four categories. The participant was instructed to guess if he or she had not perceived anything. In 20% of the trials there was actually no stimulus (empty category). These trials allowed measuring individual participants' tendency to choose one category over the other. The trial ended after the participant made the response.

Each participant performed a total of 160 trials in each experimental session. Stimulus categories had to be presented both left and right of fixation equally. As a result, there were 20 possible combinations with the 5 categories of stimuli. All combinations had to be presented in both the left and right eye equally. Next, the visibility-check question had to refer to all stimulus combinations equally, which combines to a total of 80 trials. All conditions (category combinations, left/right of fixation, left/right eye and visibility-check) were fully counterbalanced within participants. These 80 trials were performed twice, resulting in a total of 160 trials.

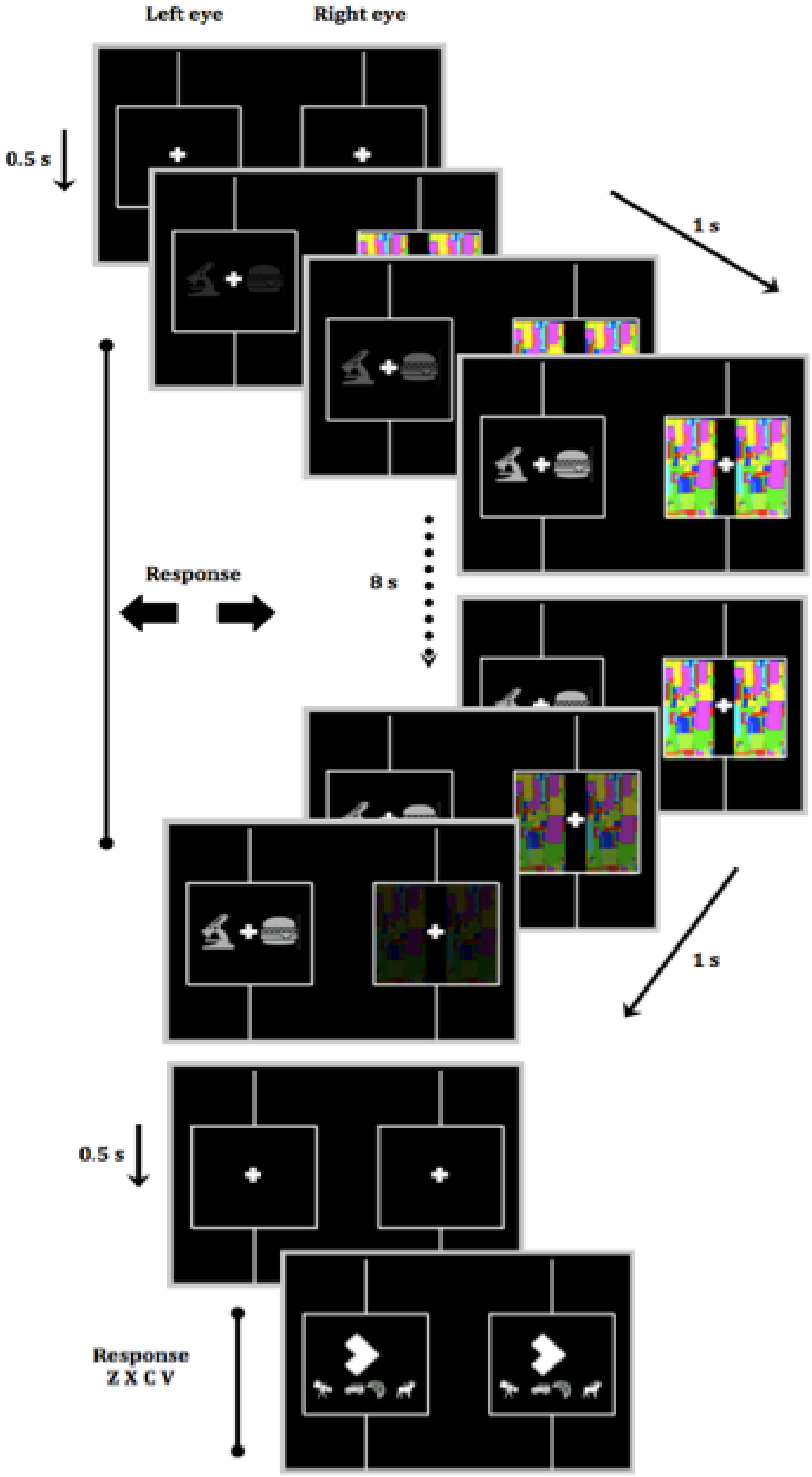

Figure 1: Schematic stimulus presentation of a single trial.

All participants took part in two identical experimental sessions on two different days with at least one day in between. One session was performed when participants were hungry (hunger condition). The other session was performed when participants were not hungry (not-hunger condition). The order of these conditions was counterbalanced between participants and gender. In the hunger condition, participants were instructed not to eat and drink soda five hours prior the experiment. In the not-hunger condition, participants were instructed to eat before starting the experiment.

At the end of both experimental sessions, the participant had to indicate how hungry they were on a scale from 1 to 10. At the end of the second experimental session, the participant had to fill out an exit interview and a stimulus questionnaire. The exit interview was included to gain extra information about participants' personal life and questions that were related to the b-CFS task. The interview consisted of questions such as, "Are you a vegetarian?", "Do you have problems with vision now or in the past?" and "Did you most of the time see one or two images appear through the color masks?". The stimulus questionnaire contained all experimental used stimuli from the categories "Food" and "Animal". Both stimulus categories could be seen as food. For this reason, the participant had to specify from one to seven, to what extent he or she could eat the content the picture represented. After everything was done the participant was thanked for participation and, if needed, rewarded with course credits.

Design

The experiment used a 2x10 within subject design. The experimental factors were interoceptive manipulation (2x, hungry vs. not-hungry) and the stimulus combinations (10x). The visibility-check factor (2x, same-side vs. opposite-side) was also included to ask for the category at the reported side of response (same-side) or the category at the not-reported response (opposite-side). This made it possible to assess how many times one stimulus was chosen over the other. Other factors were eye-presentation (2x, left eye vs. right eye) and side of stimulus presentation (2x, left of fixation vs. right of fixation). All these within subject factors were counterbalanced within participants.

The between subject factors were counterbalanced between participants and consisted of the Order of Conditions (2x, hungry -> not-hungry vs. not-hungry -> hungry) and Gender (2x, male vs. female).

Data Analysis

A within-subject design was used for this experiment. In this way variability between participants can be accounted for. For each category (food, animal, object and transport) the median response time (RT) was calculated in the first session (hunger condition) and compared to the median RT in the second session (not-hunger condition). The median was used because the RT's were not normally distributed (skewed to the right). Significance was tested with a 2x10 repeated measures ANOVA.

Results

Reaction time data from 27 participants (16 female, 11 male; age 20-29 years, *M* = 24, *SD* = 2.297) was obtained and analyzed. Two participants were excluded from analysis. One participant did not respond within the ten-second trial span for 35% of the 160 trials. As a result, some conditions had no RT data. The other participant did not follow the task instructions, which resulted in an unusual 100% correct opposite-side response. For all other participants this rate was between 40% and 60%. Within this analysis specific expectations existed about "Food" stimuli. For this reason, "Food" stimuli were analyzed more extensively than the other categories (animal, object and transport).

RT-data

This test serves to assess if our expectations were met. That is, if food stimuli appeared faster into visual awareness, compared to other category (animal, object and transport) stimuli, when participants were hungry. The within-subject variables were Interoceptive Condition (hunger vs. not-hunger) and the different Category stimuli (food, animal, object and transportation). For this experiment a two (interoceptive condition) by four (Category stimuli) repeated measures ANOVA was conducted. Furthermore, paired-sample t-tests were used to further analyze the RT-data.

Mauchly's test indicated that the assumption of sphericity was violated for the main effect of Category $\square^2(5) = 25.477$, $p < .001$ and the interaction effect of Interoceptive Condition*Category $\square^2(5) = 38.484$, $p < .001$. Therefore, degrees of freedom were corrected using Greenhouse-Geisser estimates of sphericity ($\varepsilon = .623$

for main effect of Category and ε = .602 for interaction effect of Interoceptive Condition*Category). The results indicated no main effect of Interoceptive Condition on RT [$F(1,26) = 1.231$, $p = .277$, $\eta_p^2 = .045$]. This demonstrates that, over all stimulus categories, participants' hunger level did not affect RT's in the b-CFS task.

However, there was a main effect for Category on RT [$F(1.87, 48.628) = 23.109$, $p < .001$, $\eta_p^2 = .471$]. This suggests differences in RT's to different stimulus categories regardless of the interoceptive condition. That is, some stimulus categories had faster RT's then other stimulus categories. Simple contrast revealed that, over both interoceptive conditions, RT's for images from the category "Animal" (M = 2.200, SD = .129) were slower than RT's for images from the category "Food" (M = 1.927, SD = .115) [$F(1, 26) = 24.054$, $p < .001$, $\eta_p^2 = .463$]. Second, RT's for the images from the category "Transport" (M = 1.831, SD = .091) were slower than RT's for images from the category "Food" (M = 1.927, SD = .115) [$F(1, 26) = 7.305$, $p < .05$, $\eta_p^2 = .219$]. Third, RT's for images from the category "Object" (M = 1.933, SD = .116) did not differ from RT's for images from the category "Food" (M = 1.927, SD = .115) [$F(1, 26) = .059$, $p = .810$, $\eta_p^2 = .002$].

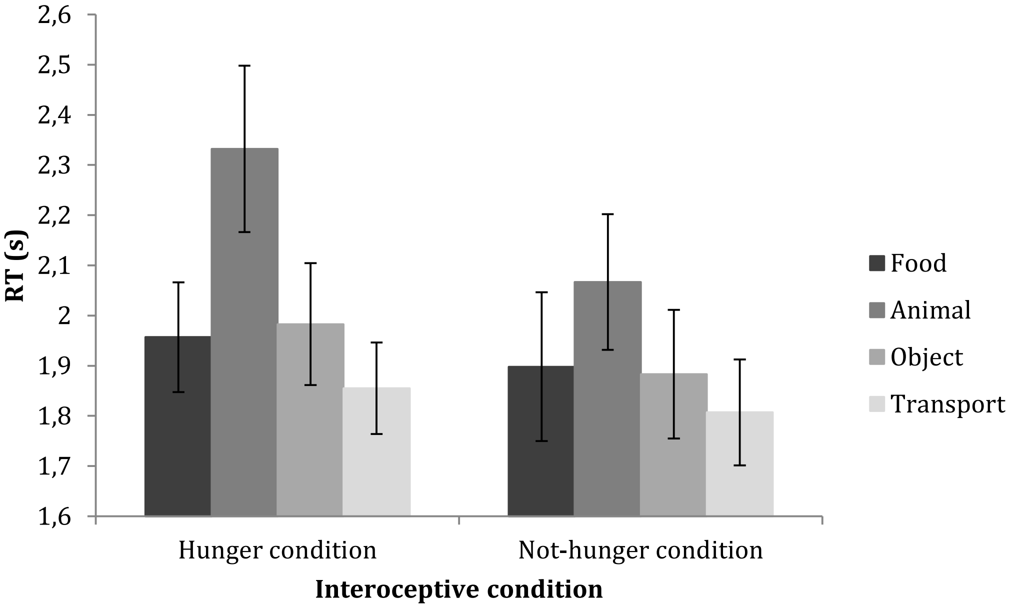

Figure 2: average RT's *to all stimulus categories over both interoceptive conditions.*

Moreover, the results indicated a marginal interaction effect of Interoceptive Condition*Category on RT, suggesting a trend with different RT's to the stimulus categories between the interoceptive conditions [*F*(1.805, 46.933) = 2.875, *p* = .072, η_p^2 = .100]. Figure 2 shows the average RT's for all categories in both interoceptive conditions. Next, we discuss the source and direction of this marginal interaction by using paired sample t-tests.

Paired sample t-test with absolute RT-data

Looking back at the hypothesis, it was expected that RT's to the category "Food" would differ between the interoceptive conditions. Also, RT's for the other categories (animal, object and transportation) would be equal between the interoceptive conditions. To test whether RT's to the stimulus categories differed between the two interoceptive conditions paired sample t-tests were used with the actual response data (absolute RT-data).

Results indicated no significant difference in RT's to the category "Food" between the hunger (*M* = 1.956, *SD* = .568) and not-hunger (*M* = 1.897, *SD* = .771) condition [*t*(26) = .472, *p* = .641]. No significant differences were found for RT's to the other categories "Animal" [*t*(26) = 1.663, *p* = .108], "Object" [*t*(26) = 1.072 *p* = .293] and "Transport" [*t*(26) = .613, *p* = .545].

Paired sample t-tests were also used to assess if RT's to the category "Food" differed with RT's to "Non-Food" categories (averaged over animal, object and transport stimuli) within the interoceptive conditions. Within the hunger condition participants showed no difference in RT's to the category "Food" (*M* = 1.956, *SD* = .568) compared to the category "Non-Food" (*M* = 2.00, *SD* = .604) [*t*(26) = -1.409, *p* = .171]. Similarly, for the not-hunger condition the difference in RT's to the category "Food" (*M* = 1.897, *SD* = .771) and the RT's to the category "Non-Food" (*M* = 1.881, *SD* = .571) was not significant [*t*(26) = .329, *p* = .745]. That is, there was no difference in RT's to the category "Food" compared to the category "Non-Food" within both interoceptive conditions. The same was done for the other stimuli categories. RT's to the category "Animal" were slower compared to the RT's to the other categories averaged (non-animal stimuli) for both the hunger condition [*t*(26) = 4.514, *p* < .001] and the not-hunger condition [*t*(26) = 4.589, *p* < .001]. RT's to the category "Object" did not differ with RT's to the category "Non-Object" in the hunger condition [*t*(26) = - .305, *p* = .763] and the not-hunger condition [*t*(26) = .378, *p* = .709]. Furthermore, RT's to the category "Transport" were faster then RT's to the category “Non-Transport” within the hunger condition [*t*(26) = -3.956, *p* = .001] and the not-hunger condition [*t*(26) = -2.684, *p* = .012].

Paired sample t-test with relative RT-data

Here, a difference in RT’s to “Food” and “Non-Food” stimuli was tested between the interoceptive conditions with relative RT-data. The relative RT-data was calculated by dividing the RT’s of the category “Food” with the RT’s of the category “Non-Food” within each interoceptive condition. Absolute RT-data, within the participant, is depended on the specific visual characteristics of the different stimulus categories. Furthermore, the variance between participants, caused by inter-personal differences in continuous flash suppression sensitivity, could be accounted for using relative RT-data.

Results indicated no significant difference between the two interoceptive conditions with regard to relative RT’s to the category “Food” compared to the category “Non-Food” [*t*(26) = -.485, *p* = .632]. This suggests that hunger did not affect participants’ RT’s between the categories “Food” and “Non-Food”. For the other categories, marginal differences were found for “Animal” [*t*(26) = 1.867, *p* = .073] and “Transport” [*t*(26) = -1.913, *p* = .067]. This suggests that there was a trend in larger differences in RT’s between the categories “Animal”/”Transport” and “Non-Animal”/”Non-Transport” in the hunger condition compared to the not-hunger condition. No significant difference was found for the category “Object” [*t*(26) = -.436, *p* = .667].

Relative RT’s were also calculated to assess whether RT’s to the category “Food” with each of the other categories (animal, object, transport) differed in the hunger condition compared to the not-hunger condition.

Paired sample t-tests revealed a marginal difference in relative score for the categories “Food” and “Animal” in the hunger (*M* = .865, *SD* = .125) condition compared to the not-hunger (*M* = .918 *SD* = .111) condition [*t*(26) = -1.986, *p* = .058]. That is, there was a tendency for participants to have a larger RT difference between the categories “Food” and “Animal” in the hunger condition compared to the not-hunger condition. No significant differences between the interoceptive conditions was found for the categories “Food” with ”Object” [*t*(26) = - .302, *p* = .765] and “Food” with ”Transport” [*t*(26) = .481, *p* = .635]. That is, difference in RT’s for “Food” with

“Object” or “Food” with “Transport” did not differ between the hunger and not-hunger condition.

RT-data from Organic vs. non-organic stimuli

From an ecological perspective, both “Food” and “Animal” images could be regarded as food. Therefore, all stimulus categories were divided into organic stimuli and non-organic stimuli. The organic stimuli consisted of the stimulus categories “Food” and “Animal”. The non-organic stimuli consisted of the stimulus categories “Object” and “Transport”. This section looked at any differences in RT’s between organic and non-organic stimuli and if any differences were found for organic stimuli between the interoceptive conditions. Paired sample t-tests were conducted to assess for any differences within and between the interoceptive conditions.

Within the hunger condition, results showed a significant difference in RT’s to organic (*M* = 2.067, *SD* = .66) compared to non-organic (*M* = 1.910, *SD* = .52) stimuli [*t*(26) = 3.727, *p* = .001]. Significant results were also found within the not-hunger condition for organic (*M* = 1.930, *SD* = .68) compared to non-organic (*M* = 1.838, *SD* = .58) stimuli [*t*(26) = 2.506, *p* = .019] (figure 3).

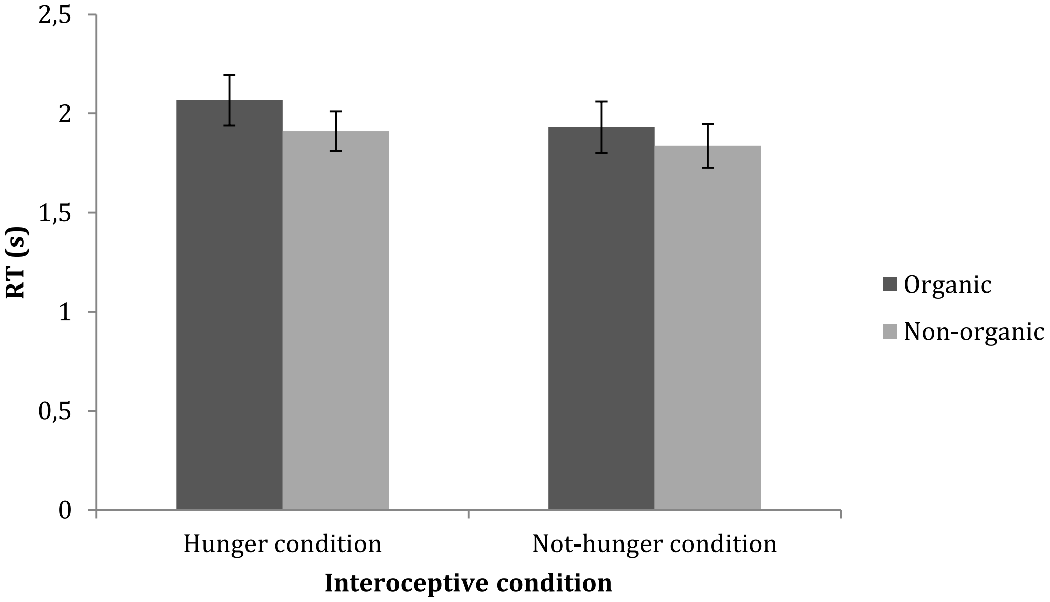

Figure 3: average RT to organic stimuli and non-organic stimuli within each interoceptive condition.

Nevertheless, no significant difference was found for RT's to organic stimuli between the hunger and not-hunger condition. Similarly, no difference in RT's was found for non-organic stimuli between the hunger and not-hunger condition (all $p >$ .25).

Category "Food" combinations versus "Non-Food" combinations

There were four categories (five including the no-stimulus category), resulting in 10 different category combinations within the b-CFS task. This section looked at possible differences in RT's between combinations that did include the category "Food" versus combinations that did not include the category "Food". This served to test whether RT's to combinations with "Food" per se differed from RT's to combinations with no "Food" category, regardless of the response choice (food or non-food). During binocular rivalry, pop-out stimuli in a specific eye were known to enhance dominance of the ipsi-ocular percept (Ooi & He, 1999). For each participant, the median RT from all "Food" combinations and the median RT from all "Non-Food" combinations was calculated and tested with paired sample t-tests.

Results showed a significant difference in RT's to "Food" combinations (M = 1.956, SD = .594) compared to "Non-Food" combinations (M = 2.022, SD = .626) within the hunger condition [$t(26) = -2.676$, $p = .013$]. Similarly, within the not-hunger condition this effect was also significant for "Food" combinations (M = 1.832, SD = .658) compared to "Non-Food" combinations (M = 1.906, SD = .558) [$t(26) = -2.533$, $p = .018$]. However, this effect of food preference did not differ between the interoceptive conditions (all $p >$.24).

Category preference

This section examined the preference for a category and if these preferences differed between the interoceptive conditions. The preference for a category is the potency for a category to break through suppression faster than another concurrently presented category. Here, the response choice was of importance rather than the response speed. It was expected that the preference for the category "Food" would be higher in the hunger condition compared to the not-hunger condition. This preference was calculated by counting the number of times "Food" was chosen over each of the other categories (animal, object and transport). Next, this number was divided by the total amount of trials, which included both categories, and multiplied by 100 (% of the trials). This was done for all four categories. For this analysis, a two (Interoceptive condition) by four (Stimulus Category) repeated measures ANOVA was used. Furthermore, paired-sample t-tests were used to further analyze the category preference.

Mauchly’s test indicated that the assumption of sphericity was violated for the main effect of Category Preference $\square^2(5) = 11.092$, p = .050. Therefore, degrees of freedom were corrected using Greenhouse-Geisser estimates of sphericity (ε = .754). Results showed no main effect of Interoceptive Condition on preference [*F*(1, 26) = .147, *p* = .706, η_p^2 = .006] suggesting no difference in category preference between both interoceptive conditions.

However, results did indicate a main effect of Stimulus Category on preference [*F*(2.262, 58.820) = 39.774, *p* < .001, η_p^2 = .605]. That is, some categories were chosen more often than other categories regardless of the interoceptive condition. Simple contrasts revealed that, over both interoceptive conditions, preferences for the category “Animal” (*M* = 40.018, *SD* = 1.368) were lower than preferences for the category “Food” (*M* = 56.121, *SD* = .912) [*F*(1, 26) = 64.703, *p* < .001, η_p^2 = .713]. Second, preferences for the category “Object” (*M* = 47.599, *SD* = .862) were lower than preferences for the category “Food” (*M* = 56.121, *SD* = .912) [*F*(1, 26) = 33.894, *p* < .001, η_p^2 = .566]. Third, preferences for the category “Transport” (*M* = 56.262, *SD* = 1,064) did not differ with preferences for the category “Food” (*M* = 56.121, *SD* = .912) [*F*(1, 26) = .011, *p* = .916, η_p^2 = .00]. This suggests that the categories “Food” and “Transport” broke through suppression more readily than the categories “Animal” and “Object”.

There was no interaction effect between the variables Interoceptive Condition and Stimulus Category on preference [*F*(3, 78) = .351, *p* = 0.788, η_p^2 = .013] suggesting no difference in category preference between the interoceptive conditions. That is, the preference for certain stimulus categories over others did not change when participants were hungry. Figure 4 shows the averaged preference for each category over both interoceptive conditions.

Paired sample t-test with absolute values

Paired sample t-tests were conducted to test for any differences in preference for a category between the interoceptive conditions.

Results showed no differences in preference for the category "Food" in the hunger (*M* = 56.269, *SD* = 6.593) compared to the not-hunger (*M* = 55.974, *SD* = 7.605) condition [*t*(26) = .145, *p* = .886]. No significant differences were found for the other categories "Animal" [*t*(26) = .727, *p* = .474], "Object" [*t*(26) = - .152, *p* = .880] and "Transport" [*t*(26) = - .872, *p* = .391]. This suggests that hunger did not significantly change preferences for "Food" or any other category.

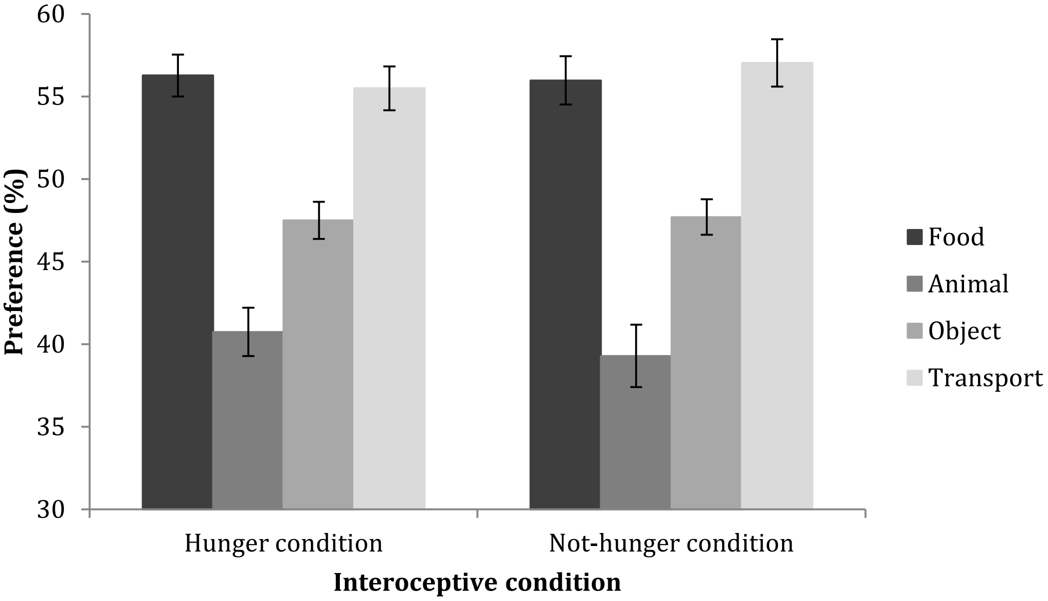

Figure 4: average preference for each category over both interoceptive conditions.

Here, differences in preference for "Food" compared to preference for "Non-Food" stimuli (averaged over animal, object and transport) were tested within the interoceptive conditions. The preference for "Food" (*M* = 56.269, *SD* = 6.593) compared to "Non-Food" (*M* = 47.910, *SD* = 2.198) was significant within the hunger condition [*t*(26) = 4.941, *p* < .001]. Similarly, for the not-hunger condition, the preference for "Food" (*M* = 55.974, *SD* = 7.605) stimuli compared to "Non-Food" (*M* = 48.009, *SD* = 2.535) stimuli was significant [*t*(26) = 4.081, *p* < .001]. That is, the preference for "Food" was higher than the preference for "Non-Food" in both interoceptive conditions. Next section looks at possible difference in preference for "Food" and "Non-Food" stimuli between both interoceptive conditions.

Paired sample t-test with relative values

The relative score was calculated by dividing preference for “Food” by preference for “Non-Food” within the hunger condition. The same was done for the not-hunger condition. Paired sample t-tests were conducted with these relative scores.

Results showed no significant difference in preference for “Food” over “Non-Food” between the hunger (*M* = 1.183, *SD* = .193) and not-hunger (*M* = 1.177, *SD* = .224) condition [*t*(26) = .096, *p* = .925]. That is, hunger did not change the preference for “Food” stimuli. No significant differences between the interoceptive conditions were found for the categories “Animal”, “Object” or “Transport” (all *p* > .35).

The relative score of preference for “Food” and preference for “Animal” in the hunger condition was compared to the relative score of preference for “Food” and preference for “Animal” in the not-hunger condition. The same was done for the preference of “Food” with the preference for “Object” and the preference of “Food” with the preference for “Transport”.

Results indicated no difference in relative scores for “Food” with “Animal” preferences between the hunger (*M* = 1.445, *SD* = .384) and not-hunger (*M* = 1.587, *SD* = .822) condition [*t*(26) = -1.011, *p* = .321]. No significant difference was found for “Food” with “Object” preferences between the hunger (*M* = 1.198, *SD* = .251) and not-hunger (*M* = 1.182, *SD* = .214) condition [*t*(26) = .277, *p* = .784]. Likewise, no difference for “Food” with “Transport” preferences between the hunger (*M* = 1.032, *SD* = .210) and not-hunger (*M* = .990, *SD* = .195) condition was found [*t*(26) = .664, *p* = .513]. That is, the difference in preference between “Food” and the other categories did not change when participants were hungry.

Category preference of food over other categories

The previous section looked at the preference of a particular category over all the other categories in general. This section looked at the preference food stimuli had over one of the other categories. In the b-CFS task each trial consisted of two simultaneously presented stimulus categories. The preference for “Food” could depend on the type of category presented next to it. A repeated measure ANOVA was conducted with the variables Interoceptive Condition (hungry vs. not-hungry) and Food Combinations (food-animal, food-object and food-transport).

Results showed no main effect for Interoceptive Condition on preference [$F(1, 26) = .021$, $p = .886$, $\eta_p^2 = .001$]. That is, the sensation of hunger did not change the preference for food over each of the other categories.

A main effect for Food Combinations was found [$F(2,50) = 15.988$, $p < .001$, $\eta_p^2 = .381$]. This suggests, that the preference for "Food" was significantly different and depended on the type of category presented next to it. Simple contrast revealed that, over both interoceptive conditions, preference of "Food" over "Animal" ($M = 61.837$, $SD = 1.482$) was higher then the preference of "Food" over "Object" ($M = 56.118$, $SD = 1.380$) [$F(1,26) = 9.287$, $p = .005$, $\eta_p^2 = .263$]. The preference of "Food" over "Object" ($M = 56.118$, $SD = 1.380$) was higher then the preference of "Food" over "Transport" ($M = 50.409$, $SD = 1.575$) [$F(1,26) = 8.709$, $p = .007$, $\eta_p^2 = .251$]. This suggests that the preference for "Food" was highest when the category "Animal" was presented next to it.

An interaction effect of Interoceptive Condition*Food Combinations was not significant [$F(2,52) = .748$, $p = .478$, $\eta_p^2 = .028$]. This implies that being hungry did not influence the preference of "Food" stimuli over any other category. Figure 5 shows the average preference of "Food" over the remaining 3 categories in both interoceptive conditions.

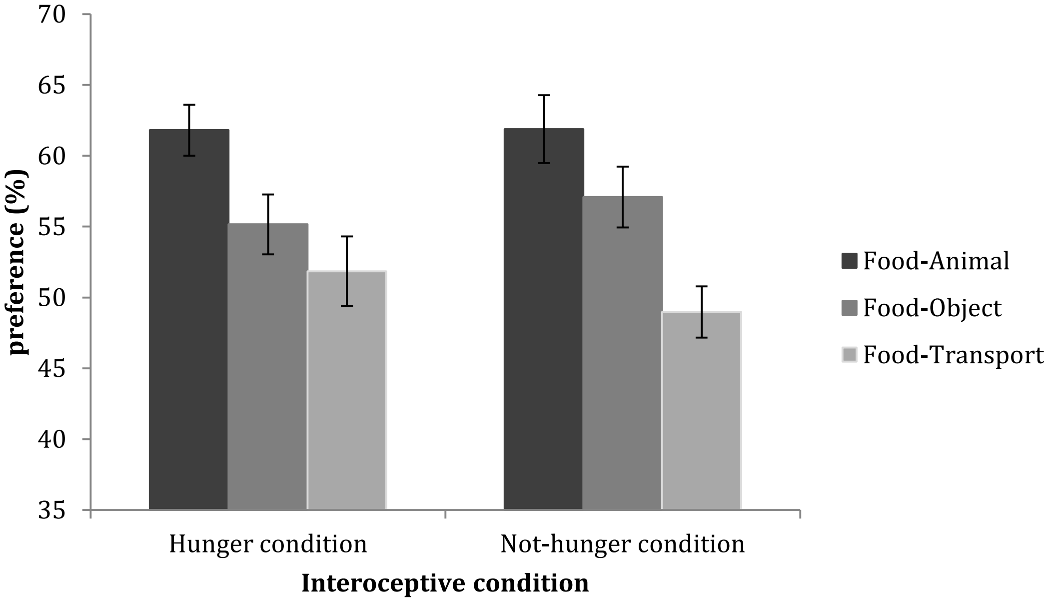

Figure 5: average preference of food over other categories (animal, object and transport) over both interoceptive conditions.

Paired sample t-test with absolute values

To see if particular food-category combinations differed between the interoceptive conditions paired sample t-tests were conducted. These tests revealed no significant difference for the preference of “Food” over “Animal” in the hunger (*M* = 61.80, *SD* = 9.30) condition compared to the not-hunger (*M* = 61.875, *SD* = 12.434) condition [*t*(26) = - .025, *p* = .980]. Moreover, the difference for “Food” over “Object” preference was not significant between the hunger (*M* = 55.157, *SD* = 10.977) and not-hunger (*M* = 57.080, *SD* = 11.157) condition [*t*(26) = - .593, *p* = .559]. Similarly, no difference was found for “Food” over “Transport” preference between the hunger (*M* = 51.852, *SD* = 12.763) and not-hunger (*M* = 48.966, *SD* = 9.379) condition [*t*(26) = .981, *p* = .336].

Test-stimuli presented in participants’ non-dominant eye

From the exit interview, participants were asked to report if they saw one or two stimuli breaking through suppression during the experiment. In half of the 160 trials, the suppressed image was presented in participants’ dominant eye. A key point in this experiment was that one of the two stimuli must break through suppression over the other. This is essential to make any inferences about awareness. Twelve participants reported seeing either one or both stimuli breaking through suppression. Seven participants reported seeing one stimulus breaking through suppression more frequently. Eight participants reported seeing two stimuli breaking through suppression more frequently. This could be explained by the presentation of the test stimuli in participants’ dominant eye, in which suppression was reduced. Therefore, a repeated measure ANOVA was conducted with only the RT’s obtained from participants’ non-dominant eye.

Mauchly’s test indicated a violation of the assumption of sphericity for main effect of Category χ^2 (5) = 28.507, *p* < .001, and the interaction effect of Interoceptive Condition*Category χ^2(5) = 41.113, *p* < .001. Therefore, degrees of freedom were corrected using Greenhouse-Geisser estimates of sphericity (*ε* = .693 for main effect of Category and *ε* = .597 for interaction effect of Interoceptive Condition*Category).

Results showed a significant main effect of Interoceptive Condition on RT [*F*(1,26) = 5.718, *p* = .024, η_p^2 = .181]. That is, RT’s in the hunger condition (*M* =

2.393, *SD* = .172) were slower compared to the not-hunger condition (*M* = 2.077, *SD* = .126) for participants' non-dominant eye. This suggests that interocular suppression is stronger when participants were hungry.

A significant main effect of Category was found on RT [*F*(2.078, 54.027) = 17.791, *p* < .001, η_p^2 = .406], suggesting different RT's to particular categories in general. Simple contrast revealed that, over both interoceptive conditions, RT's to the category "Animal" (*M* = 2.587, *SD* = .162) were slower than RT's made to the category "Food" (*M* = 2.179, *SD* = .163) [*F*(1, 26) = 15.605, *p* = .001, η_p^2 = .375]. Second, RT's made to the category "Object" (*M* = 2.123, *SD* = .130) did not differ with RT's made to the category "Food" (*M* = 2.179, *SD* = .163) [*F*(1, 26) = .664, *p* = .423, η_p^2 = .025]. Third, RT's to the category "Transport" (*M* = 2.051, *SD* = .115) did not differ with RT's made to the category "Food" (*M* = 2.179, *SD* = .163) [*F*(1, 26) = 2.754, *p* = .109, η_p^2 = .096].

Furthermore, results indicated a marginal interaction effect of Interoceptive Condition*Category on RT [*F*(1.792, 46.580) = 2.936, *p* = .068, η_p^2 = .101] suggesting a trend in different RT's to the categories in the hunger condition compared to the not-hunger condition. However, the obtained results were similar to the results obtained from both eyes. Therefore, no further analysis was conducted with the current results. The results are presented in figure 6.

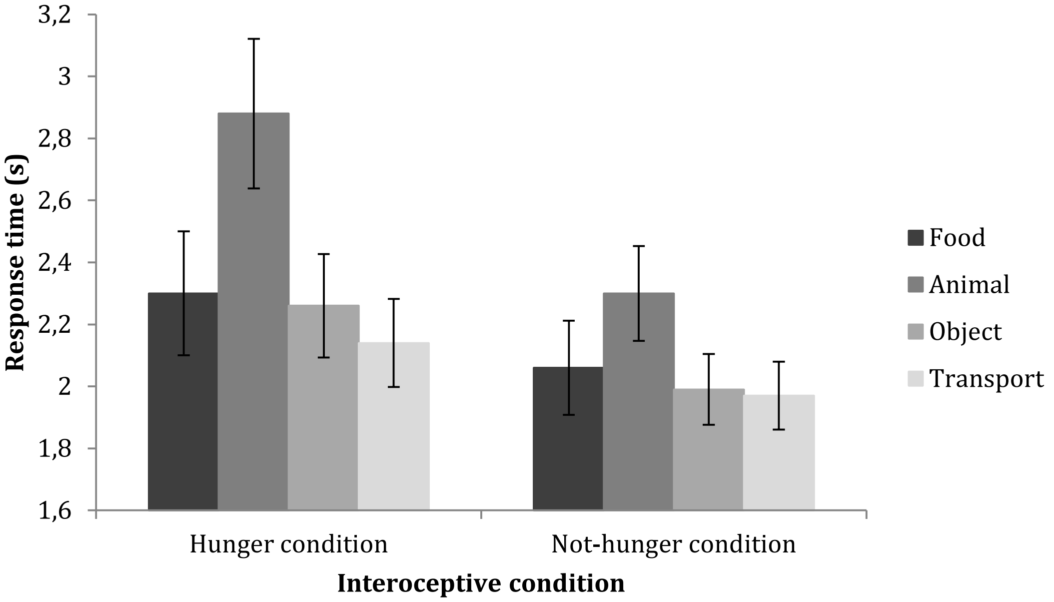

Figure 6: average RT for each category over both interoceptive conditions. RT-data obtained from participant’s non-dominant eye.

Orders of condition

Participants took part in two experimental sessions, one in which they were hungry and one in which they were not, the order of which was counterbalanced between participants. This was done to account for possible learning effects when participants were tested a second time. A repeated measures ANOVA was conducted with the variables Interoceptive Condition, Stimulus Category and a between variable Orders of Condition.

Mauchly’s test indicated that the assumption of sphericity was violated for main effect of Category □^{2}(5) = 24.783, *p* < .001, and the interaction effect of Interoceptive Condition*Category □^{2}(5) = 37.777, *p* < .001. Therefore, degrees of freedom were corrected using Greenhouse-Geisser estimates of sphericity (ε = .622 for main effect of Category and ε = .606 for interaction effect of Interoceptive Condition*Category).

Results showed an interaction effect for Interoceptive Condition*Orders of Condition on RT [*F*(1, 25) = 5.484, *p* = .009, η_p^2 = .264] reflecting a main effect for session. The means from each session in both orders of conditions are depicted in figure 7. For both orders of conditions, RT’s in the first session were slower than the second session. These results indicated that RT’s from the interoceptive conditions depended on the order of condition. This could be due to a learning effect that occurred when participants were tested a second time. Paired sample t-test revealed a significant difference in RT’s between the first (*M* = 2.109, *SD* = .73) and second (*M* = 1.837, *SD* = .49) session [*t*(26) = 2.881, *p* = .008]. That is, participants had slower RT’s in the first session compared to the second session.

There was no interaction effect of Category*Order of Condition on RT [*F*(1.867, 46.676) = .201, *p* = .803, η_p^2 = .008]. The order in which conditions were presented did not have any effect on RT’s to particular categories.

Results showed a marginal interaction effect of Interoceptive Condition*Category*Orders of Condition [*F*(1.817, 45.416) = 2.932, *p* = .068, η_p^2 = .105]. Within the first section, RT-data from both eyes was analyzed without the between subject variable Order of Condition. This section included the between subject variable Order of Condition. However, the current results did not differ much with results obtained from the first section. For this reason, including Order of Condition as a between subject variable in the analysis with RT data obtained from participants' non-dominant eye was not conducted.

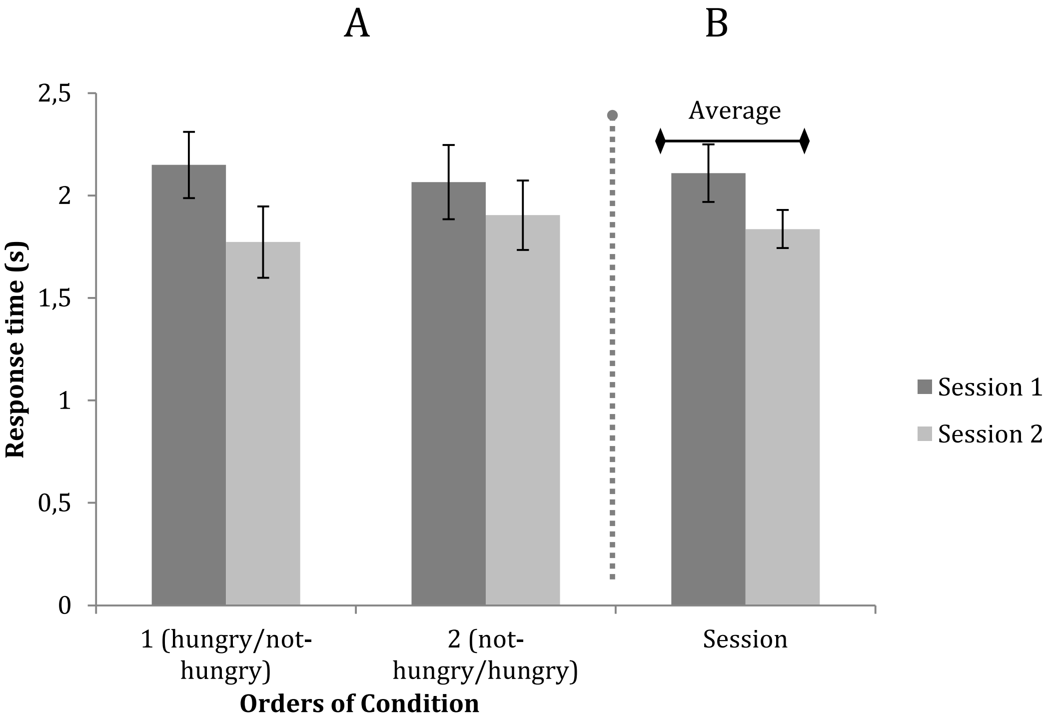

Figure 7: A: average RT for each session from both Order of Conditions (hungry/not-hungry vs. not-hungry/hungry). B: the average RT for each session.

Hunger rating scale

All participants rated their hunger on a scale from 1 (not at all) to 10 (very hungry) after both experimental tasks. Paired sample t-test revealed a significant difference in hunger rating scale between the hunger (*M* = 7.59, *SD* = .797) and not-hunger (*M* = 3.11, *SD* = 1.649) condition [*t*(26) = 13.214, *p* < .001]. That is, participants were hungrier in the hunger condition compared to the not-hunger condition. The difference between these rating scores was calculated to test if this rating-difference has a relation with the difference in RT's to different categories between the two interoceptive conditions.

Results indicated no significant correlations with the hunger rating difference and the difference found in RT to the categories over both interoceptive conditions (all $p > .65$). That is, no relation existed in differences in RT's to categories between the interoceptive conditions and the difference in hunger rating.

Visibility-check

Participants performed a total of 160 trails. At the end of each trial, participants were asked to report the category of the stimulus either on the same side of participants' response (same-side response) or at the opposite side of participants' response (opposite-side response). In half of the 160 trials, participants had to report the category of the stimulus on the same-side of their response. For the other half of the trials, participants had to report the category of the stimulus on the opposite-side of their response. A key-point in the b-CFS task was that one stimulus breaks faster through suppression then the simultaneously presented stimulus in the opposite hemifield. For this reason, it would be expected that the correct same-side responses were higher than the correct opposite-side responses. The percentage correct same-side responses and the percentage correct opposite-side responses are depicted in figure 8.

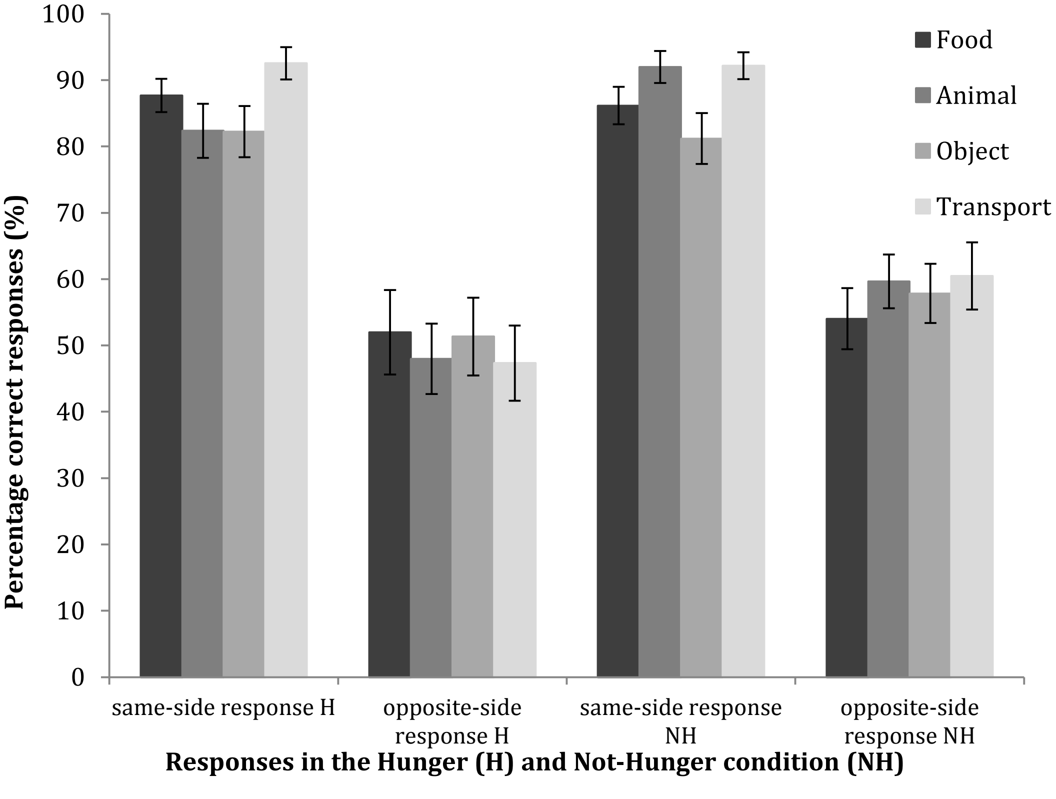

Figure 8: averaged correct response and not-reported response for all stimuli categories in the hunger (H) and not-hunger (NH) condition.

The within subject variables were Interoceptive Condition (hunger vs. not-hunger) and Side Response (same-side vs. opposite-side). A two (Interoceptive Condition) by two (Side Response) repeated measures ANOVA was conducted. Furthermore, paired sample t-tests were used to test whether correct same-side responses differed with the correct opposite-side responses within both interoceptive conditions. Paired sample t-tests were also conducted to test if the correct same-side responses differed over both interoceptive conditions for each category.

The results indicated no main effect of Interoceptive Condition on percentage correct responses [$F(1,26) = 2.487$, $p = .127$, $\eta_p^2 = .087$]. That is, the sensation of hunger did not affect the percentage of correct responses either on the same-side or opposite-side.

However, there was a main effect for Side Response on percentage correct responses [$F(1,26) = 215.051$, $p = .000$, $\eta_p^2 = .892$]. That is, the percentage of correct responses for same-side and opposite-side differed regardless of the interoceptive condition. In the next section, paired sample t-test were conducted to test if this difference was present for all categories.

An interaction effect of Interoceptive Condition*Side Response on percentage correct responses was not found [$F(1,26) = 2.065$, $p = .163$, $\eta_p^2 = .074$]. That is, the percentage of correct responses for both same-side and opposite-side responses did not differ between the interoceptive conditions. Next section looks at any differences in correct same-side responses between the interoceptive conditions.

Paired sample t-tests

Paired sample t-test revealed significant differences between the correct same-side responses and the correct opposite-side responses in both the hunger and not-hunger condition. Within the hunger condition, correct same-side responses ($M = 86.21$, $SD = 13.22$) were significantly greater then correct opposite-side responses ($M = 49.17$, $SD = 23.52$) [$t(26) = 9.466$, $p < .001$]. Similarly, for the not-hunger condition correct same-side responses ($M = 87.87$, $SD = 12.49$) were significantly greater than correct opposite-side responses ($M = 58.00$, $SD = 19.95$) [$t(26) = 10.895$, $p < .001$]. That is, participants performed significantly better on same-side responses then opposite-side responses in both interoceptive conditions.

Results indicated a significant difference in percentage correct same-side responses for the category "Animal" in the hunger (*M* = 82.37, *SD* = 21.21) condition compared to the not-hunger (*M* = 91.98, *SD* = 12.48) condition [*t*(26) = -2.487, *p* = .020]. That is, participants had a significantly greater percentage of correct same-side responses to the category "Animal" in the not-hunger condition compared to the hunger condition. No significant differences in percentage correct same-side responses were found for the categories "Food", "Object" and "Transport" between the interoceptive conditions (all *p* > .5).

The level of chance to correctly report a stimulus category was 25% (4 categories). Ideally, correct opposite-side responses would not differ from the chance level of 25%. However, t-tests revealed significant differences for correct opposite-side responses compared to chance level for the categories "Food" (*M* = 50.06, *SD* = 33.13) [*t*(26) = 3.93, *p* = .001], "Animal" (*M* = 47.97, *SD* = 27.56) [*t*(26) = 4.33, *p* < .001], "Object" (*M* = 51.34, *SD* = 30.50) [*t*(26) = 4.488, *p* < .001] and "Transport" (*M* = 47.33, *SD* = 29.40) [*t*(26) = 3.947, *p* = .001] within the hunger condition. Similarly, for the not-hunger condition significant differences for correct opposite-side responses compared to chance level were found for the categories "Food" (*M* = 54.03, *SD* = 23.88) [*t*(26) = 6.317, *p* < .001], "Animal" (*M* = 59.64 *SD* = 21.05) [*t*(26) = 8.551, *p* < .001], "Object" (*M* = 57.84, *SD* = 23.24) [*t*(26) = 7.341, *p* < .001] and "Transport" (*M* = 60.48, *SD* = 26.33) [*t*(26) = 7.004, *p* < .001]. This suggests that participants performed above chance level on opposite-side stimulus categorization.

Participants' tendency to choose a particular category

In 32 of the 160 trials, just one stimulus category was presented next to an empty category (no stimulus). The baseline gamble responses were the reported responses when the visibility-check asked to report the empty side. This allowed measuring participants' tendency to choose a particular category per se. The baseline gamble rates are depicted in figure 9. Paired sample t-tests were conducted to test for participants' tendency to choose a particular category per se.

Within the hunger condition, results indicated significant differences in reporting the category "Object" (*M* = 40.02, *SD* = 16.94) over the category "Food" (*M* = 16.78, *SD* = 8.78) [*t*(26) = 5.356, *p* < .001], "Animal" (*M* = 19.67, *SD* = 11.06) [*t*(26) = 4.058, *p* < .001] and "Transport" (*M* = 23.52, *SD* = 11.11)[*t*(26) = 3.589, *p* = .001]. Furthermore, a difference was found for reporting the category "Transport" (*M*

= 23.52, *SD* = 11.11) over the category “Food” (*M* = 16.78, *SD* = 8.78) [*t*(26) = 2.167, *p* = .040]. No significant differences were found for the category “Animal” over “Food” and “Transport” over “Animal”(all *p* > .22). That is, within the hunger condition participants’ had the tendency to choose the category “Object” over all the other categories.

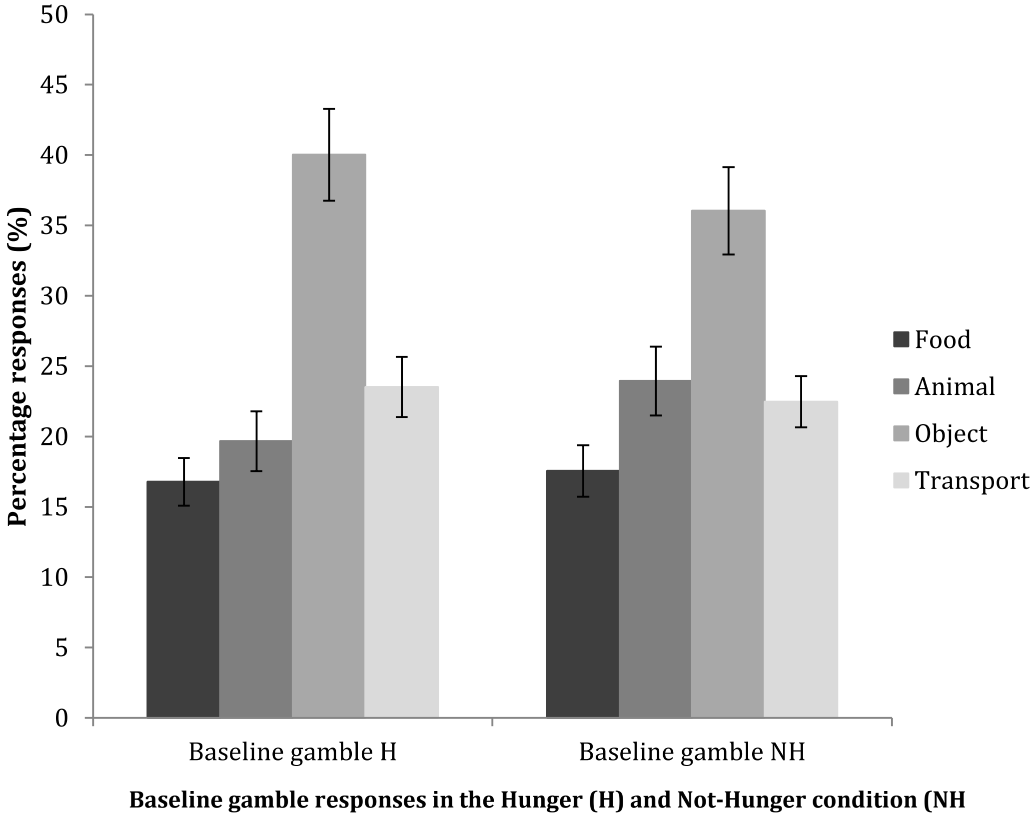

Figure 9: baseline gamble responses for all stimuli categories in the hunger (H) and not-hunger (NH) condition.

Within the not-hunger condition, results show a significant difference in reporting the category “Object” (*M* = 36.04, *SD* = 16.17) over the category “Food” (*M* = 17.55, *SD* = 9.56) [*t*(26) = 4.270, *p* < .001], “Animal” (*M* = 23.94, *SD* = 12.67) [*t*(26) = 2.384, *p* = .025] and “Transport” (*M* = 22.48, *SD* = 9.47) [*t*(26) = 3.327, *p* = .003]. Furthermore, a difference was found for reporting the category “Animal” (*M* = 23.94, *SD* = 12.67) over the category “Food” (*M* = 17.55, *SD* = 9.56) [*t*(26) = 2.101, *p* = .045]. This suggests that participants’ had a tendency to choose the category “Object” over all the other categories within the not-hunger condition.

Subsequently, paired sample t-tests were conducted to test for any difference in tendency for the categories between the interoceptive conditions. Results showed no significant differences in participants’ tendency to report a category between the hunger and not-hunger condition (all $p > .10$).

Stimulus questionnaire

At the end of the experiment participant’s filled in a questionnaire about the stimulus categories “Food” and “Animal”. Participants were asked to rate the extent to which they would like, or could eat the content of the stimulus picture from 1 (not at all) to 7 (very nice). As animal stimuli could have a potency to be seen as food whereas object and transport stimuli would not. One participant reported being a vegetarian. Figure 10 shows the mean rating for food and animal. Food stimuli (*M* = 5.08, *SD* = .792) were rated higher for consumption than animal stimuli (*M* = 1.52, *SD* = .536).

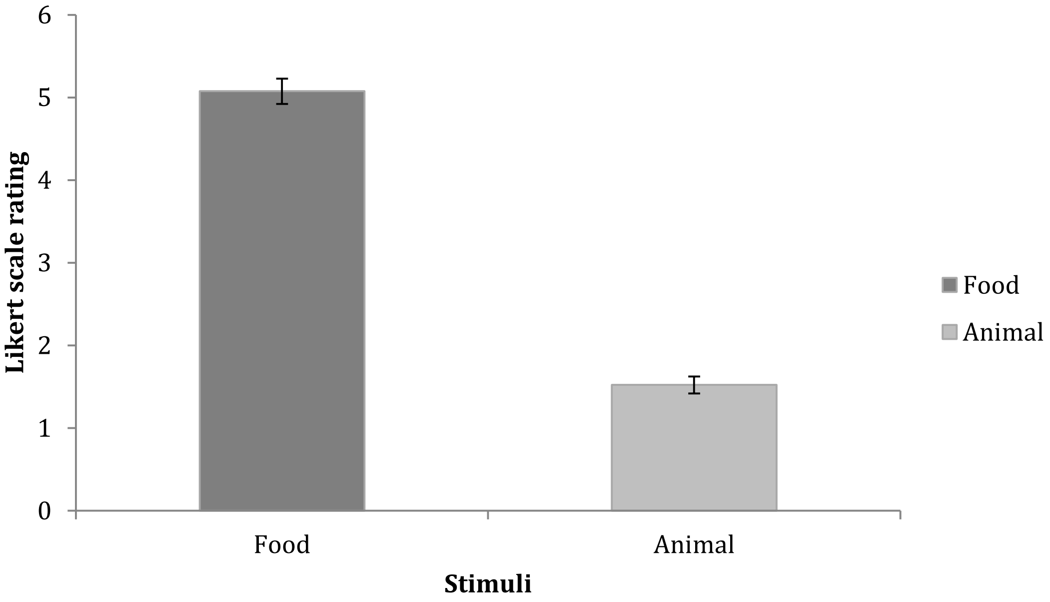

Figure 10: Average rating scores from the stimuli categories food and animal.

Discussion

The present study examines the question that interoceptive information such as hunger has an influence on the content of visual awareness. That is, whether the sensation of hunger has the potency to boost images of food into visual awareness. The results provide no evidence that interoceptive information like hunger prioritize food over other information into the content of visual awareness. An explanation may lie in the locus of the competition for awareness such that, integration of interoceptive information does not affect the competition. Here, research is focused on how rivalry works and if there are specific brain regions accountable for the change from a suppressed image to a perceptual conscious image. Researchers used single neuron recording techniques on primates to look for differences in activity during rivalry. Notably, the psychophysical performance of these trained primates was similar to that obtained from human observers, suggesting that similar neural mechanisms might underlie rivalry in both species (Leopold & Logothetis, 1996). They found that both striate (V1) and extrastriate areas (such as areas V4 and MT) showed activity changes during rivalry. Moreover, almost none of the neurons ceased to fire completely during suppression. This suggests that the transfer of visually suppressed information over these cortical areas continues, despite the absence of a conscious percept. Moreover, these areas are in an anatomical position to integrate information from ascending and descending visual streams, and interact with structures that are crucial for object vision. Sheinberg and Logothetis (1997) assessed the role of the inferotemporal cortex in primates during rivalry. The inferotemporal cortex, a region just in front of area V4, has an essential role in higher visual processing such as pattern perception and object recognition (Sheinberg & Logothetis, 1997). They found, in contrast to neurons in areas V4 and MT, no activity of the inferotemporal neurons during the suppression of the stimulus. This indicates that this area represents a stage of processing beyond the resolution of perceptual conflict. This latter remark might play a crucial role in interpreting the results of this present study. The modulation of information from different modalities (e.g. interoceptive and visual information) could congregate too highly, in the hierarchy of visual processing, to bias competition for awareness. Within the Global Workspace theory (Baars, 1988; Dehaene & Naccache, 2001), various unconscious processes or modules are presented in a workspace to compete or make coalitions to set the content of consciousness. Here the interoceptive and visual modules seem not to compete or make coalitions with each other to set the content of consciousness. Thus, interoceptive information (i.e. hunger) does not bias the competition in visual information for cortical and cognitive processing.

Another possible explanation is given by Lupyan and Ward (2013) and refers to the Biased Competition Theory (Desimone & Duncan 1995). According to this theory, each object presented within the visual field competes for cortical representation and cognitive processing. Other mental processes such as bottom-up and top-down systems could bias this process. Lupyan and Ward (2013) found that hearing a valid verbal label (e.g. the word “pumpkin”) helped participants to become aware of the mere existence of the corresponding object (e.g. image of a pumpkin). They postulate that information that arises from the verbal label generates a mental picture, which serves as a top-down process that biases the competition of the presented objects for cortical representation and cognitive processing. If this mental picture corresponds with the information that arises from the visual system, the object will be prioritized into visual awareness. During the CFS task, visual information does not activate any semantic knowledge about the object (Kang, Blake & Woodman, 2011). The verbal label, however, does provide semantic information, which influences the cortical competition of the presented objects by forming a visual representation of the activated concept/image. Within the present study, the presented stimuli do not activate semantic information about the stimuli during the CFS task. Here, the sensation of hunger should serve as a top-down process that influences the competition for cortical representation and cognitive processing of the presented stimuli categories, by creating a mental picture. However, as the verbal word “pumpkin” in the study of Lupyan and Ward (2013) initiates a mental picture of a pumpkin, the sensation of hunger might not directly activate a clear mental picture of all sorts of food. For this reason, the precedence of food stimuli by means of this top-down system, such as a mental picture, does not seem to bias the competition for cortical representation and cognitive processing.

An interesting find, within the present study, is that response times in general are slower when participants are hungry. That is, participants had a longer suppression duration when they were hungry compared to when they were not hungry. The results also revealed differences in response times between the stimulus categories, regardless of the interoceptive manipulation. However, these differences in response times could be due to high-level information or low-level image properties. Therefore, no inferences can be made about the cause of these differences in response times between the stimulus categories. Gayet, Van der Stigchel & Paffen (2014) proposed inverting the stimulus in order to assess whether differences between conditions (stimulus categories) rely on high-level information instead of low-level image properties that could differ between the conditions. Thus, inverting the pictures, as an addition in the b-CFS task, could reveal the cause of the differences found in response times between the stimulus categories.

This study provided results that were not in accordance with the hypotheses proposed in the introduction. That is, whether the sensation of hunger has the potency to boost images of food into visual awareness. There might be some limitations present in this study, which may be accountable for this absence. The stimuli used in this experiment were gray scale pictures, which could be too abstract to activate a visual representation. Jiang et al (2006) used in their CFS-task color pictures that represented a more realistic representation of the stimuli. Additionally, the color of food is an important factor to decide whether food is still fresh or edible (Garber, Hyatt & Starr, 2000). Therefore, using colored stimuli of food could provide more reliable results. In the present study, participants had a high percentage of correctly reporting the stimulus category on the same-side of participant’s response. Additionally, the percentage of correct reported stimulus category on the opposite-side of participants’ response was also higher than expected. Participants were instructed to react as fast as possible when the content of the picture changed, either on the right or left of fixation. Moreover, it was not necessary to know the identity of the changed percept. After each trial participants had to report the stimulus category by forced choice. The high percentages of correctly reporting the stimulus categories found in this present study suggest that participants waited with their response to correctly report the stimulus category. To counter this, future could modify the task by asking to report the stimulus category ones in every 5 or 10 trials.

Thus, future research could focus on these limitations and additions to create a stronger and more definite conclusion about this topic. Idem, future research could focus on how images of food are visually processed within an Anorexia Nervosa (AN) patient group. It could be interesting to assess how high and low-calorie food is processed unconsciously within this group. Killgore, Young, Femia, Bogorodzki, Rogowska & Yurgelun-Todd (2003) assessed cortical and limbic activation when participants were viewing high- and low-calorie foods. They found activation in different brain regions for high- versus low-calorie foods. In line with this finding, Spring & Bulik (2013) tested acute AN patients and found an implicit negative affect towards unpleasant, high-calorie food. AN patients might have a fearful response to high calorie food images. Therefore, it could be interesting to assess whether this implicit negative affect is also present using the b-CFS task and if this implicit negative affect to high-calorie food differs with low-calorie food in AN patients compared to a healthy control group. Other research using b-CFS postulated that fearful faces appear faster into visual awareness then happy or neutral faces in a healthy observer group (Yang, Zald & Blake, 2007) and images of spiders (Lapate, Rokers, Li & Davidson, 2013). Thus, subcortical fear could act as a modulating factor in processing food images in AN patients. AN is a disorder that is difficult to treat, devastating for the patient, and has a high mortality rate. Central symptoms of AN are denial of low body weight, an intense fear of gaining weight or becoming fat while being underweight, and an unrealistically fat experience of the own body (American Psychiatric Association, 2002). It is clear that patients with this disorder have difficulty eating and the way they explicitly cope with food. Greater clarity is needed about the processes underlying this disorder.

Within this study, it is interesting to note that the b-CFS task set up was new to the field and could be beneficial for research into visual awareness. Within the b-CFS task, two different stimulus categories were simultaneously presented left and right of fixation. When the stimuli were presented in the non-dominant eye, only one of the two stimuli broke through suppression. Most studies, using the b-CFS task, presented only one stimulus either on the right or left of fixation. Presenting two stimulus categories simultaneously makes it possible to assess whether a difference in response times is due to a difference in awareness. Visual awareness of a stimulus is assumed to be a prerequisite for the ability to report a stimulus (Dehaene, Changeux, Naccache, Sackur & Sergent, 2006). This can be operationalized as the ability to report one's percept (Dennett, 1993; Dehaene & Naccache, 2001). Therefore, comparing participants' ability to report the identity of two concurrent stimuli at a particular point in time is important to assess whether one stimulus was accessible to awareness and the other was not. This new addition of the b-CFS task provides more information about differences in explicit awareness rather than implicitly triggered differences in response times.

General conclusion

Although hunger seems to modulate the speed at which the competition for visual processing is resolved, the present results do not provide evidence that the sensation of hunger boosts images of food into visual awareness. Additionally, the method used in this experiment can provide a new perspective on research into visual awareness.

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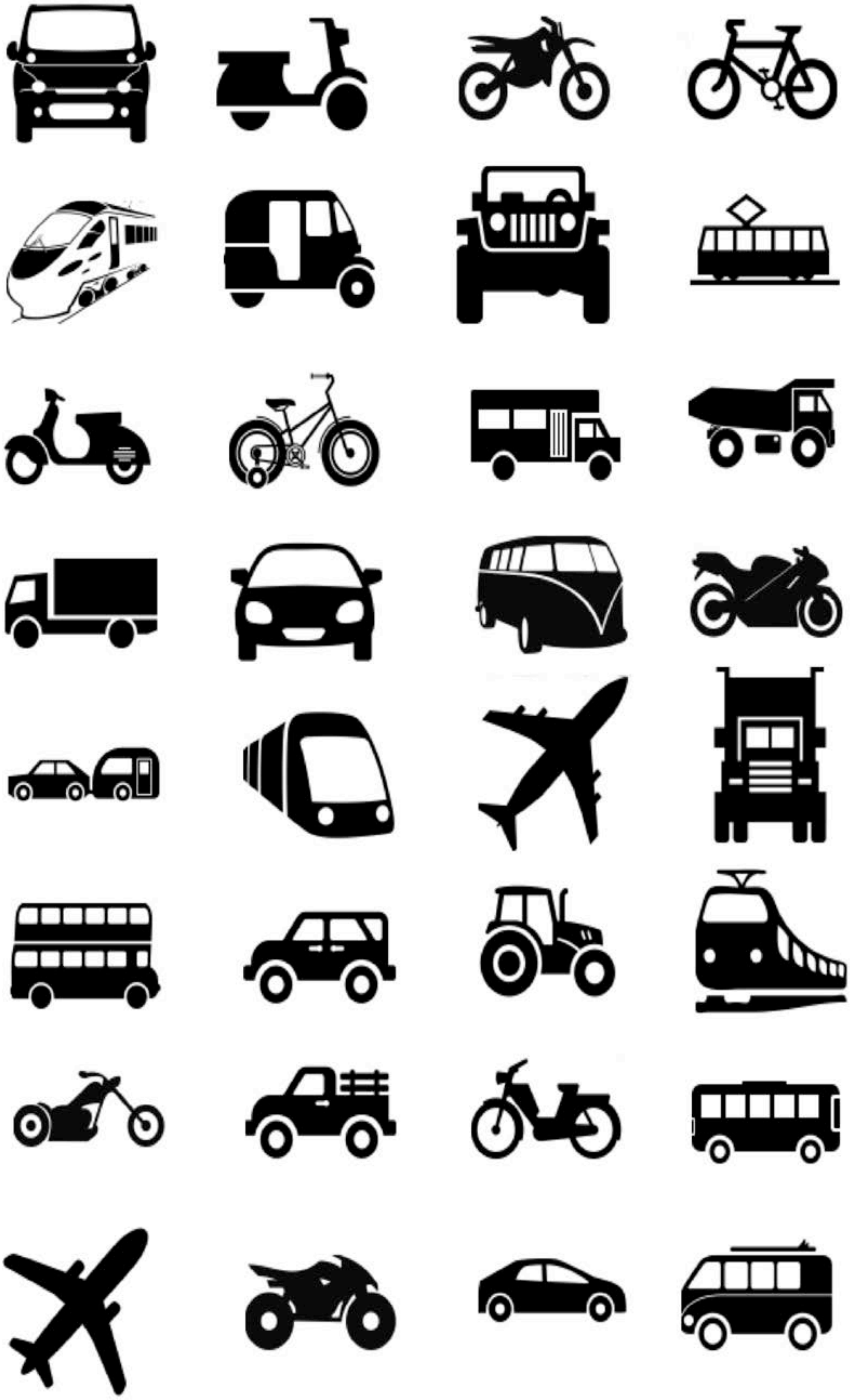
Appendix 1:

Animals

Food

Transportation



Objects