THE NATURE OF THE OBJECT MEDIATES CONSCIOUS PERCEPTION: EVIDENCE FROM REACTION TIME.

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Bachelor of Psychology, UNAM, 2015

A Thesis
Submitted to the School of Graduate Studies
Of the University of Lethbridge
In Partial Fulfillment of the
Requirements for the Degree

MASTER OF SCIENCE

Department of Kinesiology & Physical Education
University of Lethbridge
LETHBRIDGE, ALBERTA, CANADA

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Date of Defense: December 19, 2018

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DEDICATION

To all the woman in my life.

Specially my supervisor for believe in me even before I believe in myself.

My always guardian, my Mother.

And my Dad for encourage the best version of me.

ABSTRACT

Humans evolved to find and manipulate food in our environment. Studies have shown faster reaction times (RTs) and better visual attention for food stimuli. The current study investigated if the same is the case when stimuli are presented at the pre-attentive level. Food and No Food images were presented with and without a subliminal technique called b-CFS (breaking- Continuous Flash Suppression). This technique hides the image presented to one eye by distracting the other with a colorful flashing mask (i.e. Mondrian). Consistent with previous reports, an advantage for Food was found but only when the stimuli were presented without the Mondrian (No b-CFS condition). No difference in RT was found in the b-CFS condition. Modern food is complex and variant RT can be modulated by: Manipulability (whether an object can be grasped using a Whole hand grasp vs. Precision grasp) and process state (Nature vs. Processed). Results suggest that the advantage in detecting Food stimuli is only present during conscious perception.

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1. INTRODUCTION

1.1.1 Anatomy and physiology of the human visual system (The eye, Photoreceptors)

(Reviewed in Snowden, 2006; Kandel, Schwartz & Jessel, 2013)

The beginning in the process of seeing is **the eye**. Each eye is a slightly irregular spheroid with an average diameter of 24 mm and a weight of about 8 g. Within the orbit, the eyeball shares space with the extrinsic eye muscles, the lacrimal glands, and the cranial nerves and blood vessels that supply the eye and adjacent portions of the orbit and face. When the light travels through the pupil in the eye, it encounters the lenses, these anatomical features are made of a transparent, flexible tissue that makes light travel more slowly than through the air. Also, they have at least one curved surface. The cornea is the main lens. Behind the cornea is the anterior chamber filled with aqueous humour, a watery liquid that flows from the ciliary body, through fibrous strands named the Zonules of Zinn, through the pupil, and into the anterior chamber. From here the light passes through the trabecular meshwork and down the canal of Schlemm. The canal of Schlemm runs in a circle just beneath the border of the iris (the coloured bit) and the sclera (the white color part of the eye) which consists of a dense fibrous connective tissue containing both collagen and elastic fibers. The pressure of the aqueous humor is very important. It helps retain the eye’s shape and stabilizes the position of the retina and it acts like the air inside a balloon. The eye’s intraocular pressure can be measured in the anterior chamber, where the fluid pushes against the inner surface of the cornea. Normal intraocular pressure ranges from 12 to 21 mm Hg.

Next in the structure is the iris which provides an adjustable aperture and is the colored part of the eye. When light levels are high the iris constricts and the pupil, the aperture in the middle of the iris, gets smaller, limiting the amount of light passing through. When the light is dim, then the iris relaxes, allowing more light through. This is an efficient way to regulate the amount of light reaching the retina and the lens aperture is used in cameras for the same purpose. The area of the pupil when fully dilated is 16 times bigger than when it is fully constricted. The range of luminance that can be damaging to the retina is complex because with sufficient magnitude almost all wavelengths of the electromagnetic (EM) spectrum can cause harm, but the most damaging portions of EM spectrum are the UV-A (315 nm to 400 nm), UV-B (280 nm to 315 nm) and blue light portion of the visible spectrum (380 nm to 500 nm). The perception of depth relies on pupil constriction. When our pupils constrict, our depth of focus increases. Beyond the iris we reach the lens. Although the lens has less elasticity than the cornea, it has one great advantage: it is adjustable. When we want to focus on things further away, we need the lens to be stretched into a thinner shape and this is achieved by relaxing the ciliary muscles. For the visual system to work correctly the cornea needs to have in the appropriate curvature to focus light on the retina. Matching the lens system to the size of your eyeball is critical: A) Emmetropic vision- both near and far objects can be focused on the retina. B) Near sightedness- the strong lens focuses close objects on the retina, but distant objects are brought to focus in front of the retina. C) Far sightedness- the weak lens is adequate to focus distant objects but is not strong enough for close objects, which are brought to focus behind the retina.

The light must travel through all the previously mentioned eye structures for sight to happen. This operation requires a good amount of energy and this is the main reason the retina is in the back (the light sensitive layer) as blood is more easily delivered to the back of the eye than to the surface. The main cavity of the eye, behind the lens, is filled with a gelatinous substance called the vitreous humour (see Figure 1). This keeps the eyeball's shape and the retina pinned to the back of the eye. If the vitreous humour shrinks, then the retina can become detached and may need to be spot-welded back with a laser.

The retina is the site for real visual processing. Here is where transduction- the process of turning light energy into electrochemical energy within the nervous system- takes place. A disadvantage of having an inverted retina is the presence of a blind spot in each eye where the neural bundle and capillaries pass through the rest of the retina. Once the light reaches the outer segments of the photoreceptors, the sensory cells, neural processing can begin. The receptors are connected to bipolar cells and these in their turn synapse with retinal ganglion cells. The ganglion cells are important, for it is their axons that carry information from the eye on its journey towards the visual cortex. Connecting across the retina laterally are horizontal cells, then the bipolar cells are connecting with the photoreceptor cells (rods and cones, horizontal cells will have connections too) and amacrine cells between the bipolar cells with the ganglion cells (Figure 1). Each retina is divided into a temporal (close to the temporal bone) and nasal retina (close to the nasal bone). Fibers from the nasal retina cross over at the optic chiasm, whereas the fibers in the temporal retina, already positioned to see the opposite side of the visual field, do not cross.

Photoreceptors

There are two types of photoreceptors in the human eye: rods and cones. The outer segments of the rods are generally rod-shaped, and the outer segments of the cones are generally cone-shaped. The pigment that absorbs light in the rods is rhodopsin. There are three main types of cones, often called “red”, “green”, and “blue”. Red cones contain a photopigment that is most sensitive to long wavelengths of light; green cones are most sensitive to middle wavelengths of light; and the blue cones to shorter wavelengths of light. For this reason, cones are also called “long wave”, “middle-wave”, and “short wave”. It is because we have three cone types that we have color vision. Rods respond very well to extremely poor light conditions and are therefore very useful in dim conditions. It used to be thought that rods were useless in bright-light. More recent research shows that rod photoreceptors do contribute to daylight vision (Tikidji-Hamburyan et al., 2017). For the cones, the traditional view is that they are much less sensitive to changes in light levels. Hence, they are not used under dim conditions but are responsible for most of our daytime vision (Snowden, 2006).

Photoreceptors are not evenly distributed across the retina. Cones are heavily concentrated in a central area known as the fovea. When we focus an object, you get to see it accurately because of the fovea. This is the reason why we need to move our eyes (and heads) so much. Because 6 degrees eccentric to the line of sight, acuity is reduced 75%. Also important is that there are no rods on the fovea, but there are rods in high density away from there.

There is a point in the nasal retina to 12-15^0 (temporally or in direction to the temporal bone behind the orbits) known as the blind spot or optic disc. This is where ganglion cell axons and blood vessels leave the eye. It is devoid of all receptors and consequently we are blind in this area.

The last layer of cells in the retina are the retinal ganglion cells. There are two kinds of retinal ganglion cells: Parvocellular (P cells) and Magnocellular (M cells). These cells differ in size and properties. P cells distinguish between signals coming from the red cones and those coming from the green cones. For instance, some P cells will be excited by the red cones and inhibited by the green cones. The M cells do not seem to react differently to the different types of cones. Therefore, only the P cells carry information about color. On the other hand, the M cells appear much more suited to carry information about the dynamic aspects of the world such as movements and flicker. The P and M cells are intermingled in the retina. Most retinal ganglion cells send their signals via the optic nerve to the next visual structure, the lateral geniculate nucleus (LGN) of the thalamus and some M cells send their projection to superior colliculus.

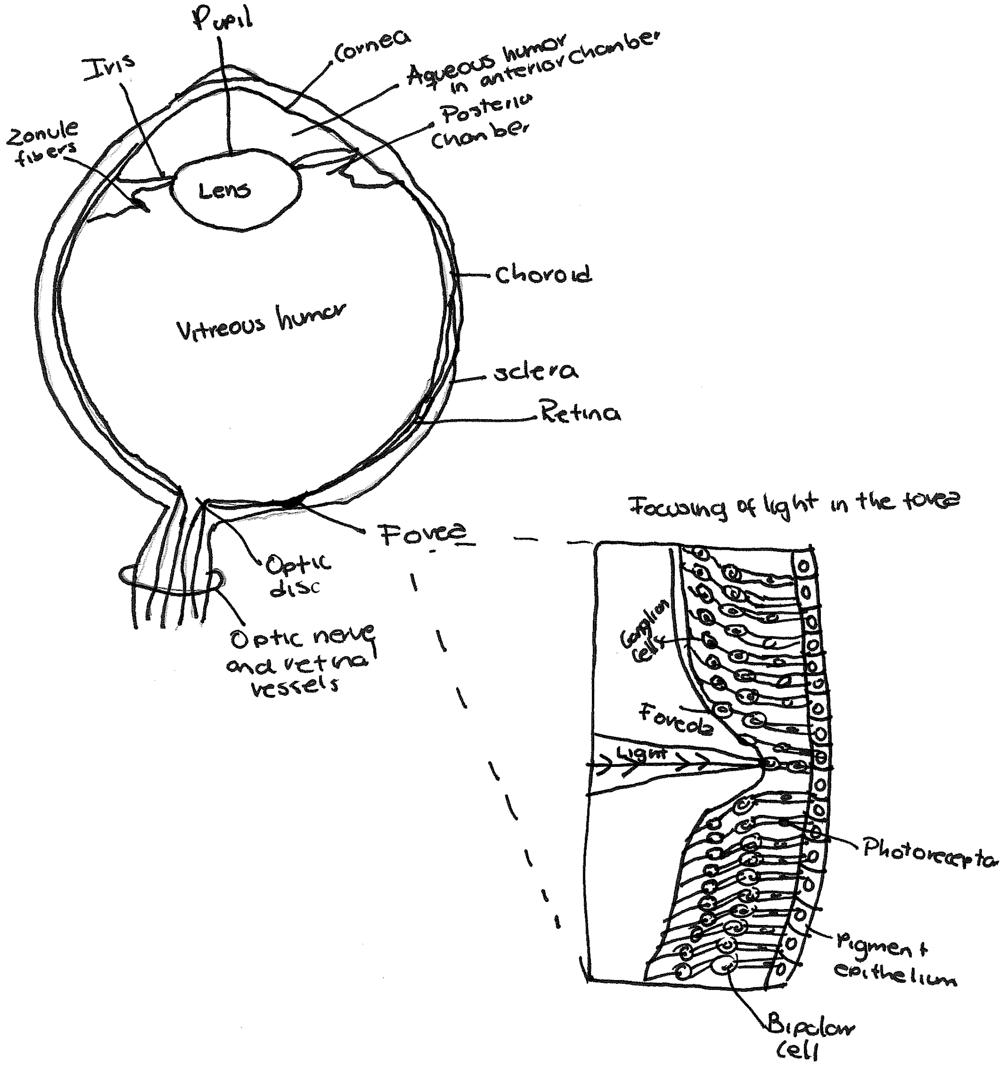


Figure 1. Anatomy of the eye. Retrieved from Purves et al., 2012

1.1.2. Beyond the eye, the optic nerve, the Lateral Geniculate Nucleus and the visual cortex.

(Reviewed in Snowden, 2006; Kandel, Schwartz & Jessel, 2013)

First, the optic nerves from the two eyes converge at a point called the optic chiasm. Here a partial decussation occurs; this means that some of the fibers cross over to the opposite side of the brain and others do not. The axons from ganglion cells on the nasal side of each retina cross and those from the temporal side of each retina do not. The result of this is that now the left bundle of nerve fibers carries information about the right visual field, and the right bundle of nerve fibers carries information about the left visual field. At this stage the optic nerve changes its name to optic tract and continues to the thalamus.

The optic tract now reaches the main relay point on the way to the cortex: the lateral geniculate nucleus of the thalamus or LGN (the egg-shaped structures of gray matter located on both sides of the third ventricle, is the largest portion of the diencephalon). In primates each LGN has six layers; the ganglion cell axons from one eye terminate in three layers and the axons from the other eye terminate in the other three (see Figure 2). Thus, information from each of the two eyes, though represented in both LGNs, is kept segregated. Layers 1 and 2 are the magnocellular layers because the M cells project to these layers. Layers 3, 4, 5 and 6 are the parvocellular layers as P cells project here. We need two magnocellular layers in each LGN because one receives input from the left eye and one from the right eye. Layer 1 on the left LGN receives its input from the right eye and is known as contralateral layer, whereas layer 2 of the left LGN receives its input from the left eye and is known as an ipsilateral layer. When it comes to the parvocellular layers, layer 3 is an ipsilateral layer and layer 4 is a contralateral layer. Layer 5 (ipsilateral) and layer 6 (contralateral) appear to be just the same as layers 3 and 4 respectively, so they seem to be redundant. In each of the LGN's six layers the cells retain what is called retinotopic mapping. This means that ganglion cells that are adjacent in the retina will project to adjacent cells in the LGN. This forms an orderly map of the visual world; adjacent cells receive information from adjacent part of the image until all the image is covered. So, each LGN has six maps of the world (one on each layer), one on top of the other. Each map contains only half the visual world with the left LGN representing the right visual field and the right LGN the left visual field.

Vision for primates is so important that a big part of our cortex is dedicated to this process. The first stage in the travel of light to the brain after the LGN is the primary visual cortex or striate cortex, also named V1. Layers of the primary visual cortex receive information straight from LGN, but some layers, especially layer 6, sends information back to the LGN. Also, another characteristic of V1 is that the information from each eye is kept separated, and the magnocellular pathway projects to a different layer of V1 than do parvocellular cells.

V1 maintains the retinotopic mapping found in LGN. Right V1 maps the left visual field and vice versa. Interestingly, there is very little overlap between the two halves of the map and yet our experience is unified. When we stare straight at something, everything to the left of a central line is being processed by our right hemisphere V1 and everything to the right by our left hemisphere V1. This 'map', however, is highly distorted. There are lots of cells in V1 devoted to the fovea (the part at which you are directly focusing your gaze) and fewer cells devoted to the parts of the image that fall further and further into the peripheral areas of the visual field.

Hubel and Wiesel in 1959, pioneers in V1 research, found that cells respond crucially to elongated lines, which is important because each cell in V1 specializes with a unique orientation and gathered within a small area of the cortex there will be a cell for all possible orientation. Thus, any line that falls on a particular part of the retina stimulates just a few cells that happen to specialize in this orientation, leaving other cells silent. When a cell shows ON and OFF regions they are named simple cells. Simple cells also have phase sensitivity, which means they are sensitive to variation for exact position. If cells do not show ON and OFF regions, they are complex cells. In addition to the retinotopic mapping, orientation preferences are organized in an ordered progression of orientation columns, each successive column having a preferred orientation slightly advanced from the column before. It is suggested that the brain contains more and more specialized cells as the information moves back from the eyes and deeper into the brain. This idea seems to be supported by another class of cell: the hypercomplex cell. These cells respond not only to a particular orientation, but also to a particular length.

Area V1 begins to put the information from the two eyes together so that we eventually have a single view of the world. About 70% of the cells in area V1 discriminate between each eye (binocular) and cells in the extrastriate areas (such as V2, V3, V4) are almost all binocular. This process of the coming together of information is the basis of stereoscopic vision.

To summarize, in V1 we have cells tuned for orientation and indirect direction of motion, binocular disparity (these cells are excited by information either from the left eye, or the right eye, or both eyes) and color. There are more than 30 visual areas beyond V1 in what is known as the extrastriate cortex.

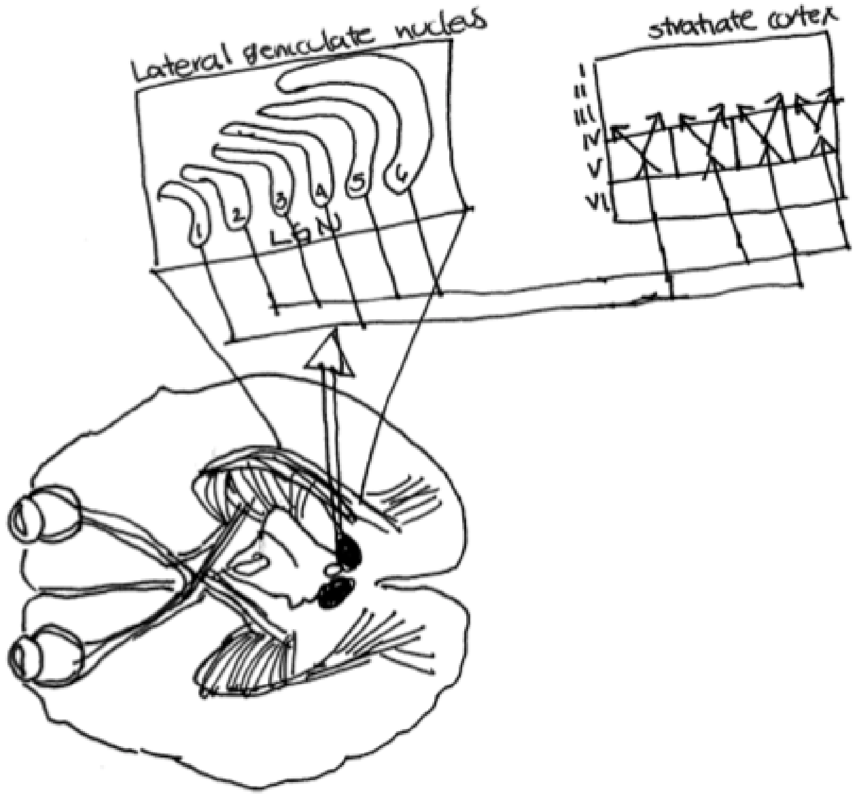


Figure 2. Lateral Geniculate Nucleus in the human brain

Description of the six layers of the LGN in the thalamus and their connection with the layers in the stratiate cortex.

1.1.3 The ‘How’ and ‘What’ visual pathways

The extrastriate areas that process vision after V1 can be divided into one of two streams- A ventral pathway into the temporal lobe, and a dorsal pathway into the parietal lobe. The organization of these pathways is based on the finding that knowing that you can see something for perception or action and being able to use this information to guide your behavior are dissociated. Melvyn Goodale and David Milner are the pioneers who found these different pathways in neurologic patients. They proposed calling the ventral stream the “What” stream and the dorsal the “How” stream. Those patients with damage of the dorsal stream could still recognize objects fine but failed to interact appropriately with these objects. James et al., (2003) reported a case study of a woman named D.F. with apperceptive agnosia due to hypoxia from carbon monoxide poisoning is a key case supporting the dual stream hypothesis. D.F. has a bilateral lesion on the lateral occipital cortex, meaning the ventral stream; she was able to guide her actions to a displayed object, but not verbally name the object. The ventral or object-recognition pathway extends from the primary visual cortex to the temporal lobe. The dorsal or action-guidance pathway connects the primary visual cortex with the parietal lobe and then with the frontal lobes (see Figure 3). The parietal lobe is a region that uses visual information to direct the movement of the eyes, and limbs that is for visuomotor integration. One area, the lateral intraparietal area, named for its location in the interparietal sulcus, is involved in representing points in space that are the targets of eye movements (e.g.reaching). The ventral pathway extends into the temporal lobe. The inferior temporal cortex (ITC) stores information about the shapes and identities of objects.

The pathways are interconnected so that information is shared. For example, movement information in the dorsal pathway can contribute to object recognition through kinematic cues. Information about movements in space derived from areas in the dorsal pathway is therefore important for the perception of object shape and is fed into the ventral pathway. Reciprocity is an important feature of the connectivity between cortical areas. All connections between cortical areas are reciprocal—each area sends information back to the areas from which it receives input. These feedback connections provide information about cognitive functions, including spatial attention, stimulus expectation, and emotional content to earlier levels of visual processing. The pulvinar nucleus in the thalamus serves as a relay between cortical areas.

The rest of the introduction will be focused on object recognition and therefore it is the function of the entire visual system but for simplicity I will highlight examples of temporal lobe and parietal lobe involvement.

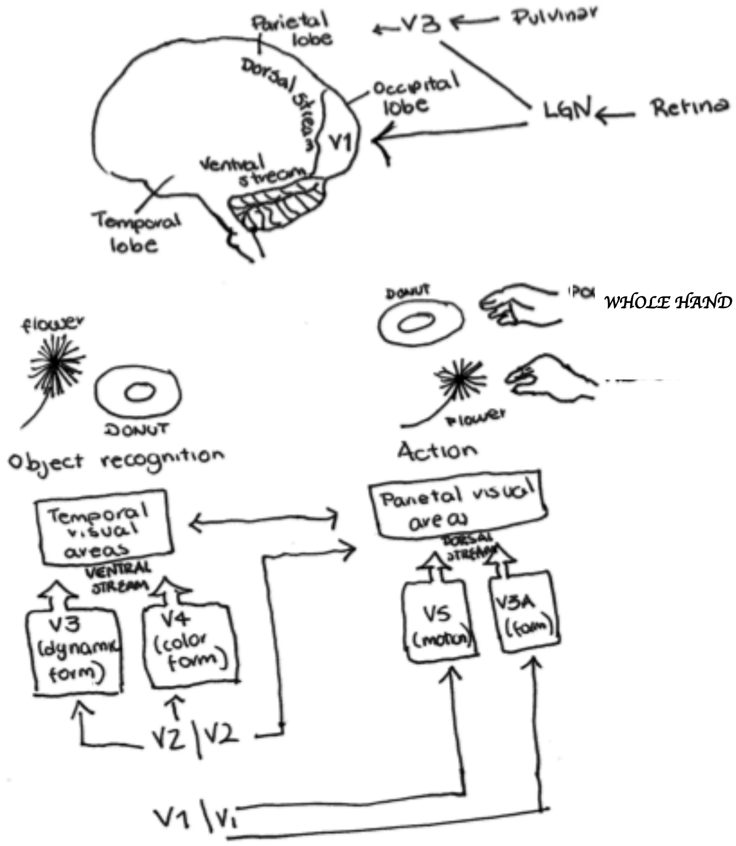


Figure 3. The ventral and dorsal visual stream.

Vision for perception ends in the temporal visual areas and vision for action in the parietal visual areas.

The posterior parietal pathway is the end of the dorsal or Where-pathway, so it has a role in transforming vision into action. An important visuospatial challenge for the brain is to converge three consecutive frames of reference: a retinotopic frame of reference, a head-centered frame of reference, and a body- centered frame of reference. Some neurons in the parietal cortex that are selectively sensitive to visual information have retinal receptive fields that are modulated depending upon the position of the eye in the orbit. These neurons are therefore combining input from the retina with information about eye position; each time the eye moves, the head centered frame of reference must be updated. Other neurons in the parietal cortex contribute to this updating by shifting the retinal location of their receptive fields in association with each saccadic eye movement. This retinotopic map or retinotopic frame of reference moves every moment but stays stable to give us a coherent image. Anything that is anchored to the frame of reference, such as the afterimage produced by a flash of light, moves with it.

Vision helps the supplementary motor and premotor systems in the frontal lobe to prepare the hands for action. When we pick up a cherry, our fingers are separated from our thumb by the width of a cherry; when we pick up an apple our fingers are separated from our thumb by the width of the apple. The visual system interacts to adjust the grip width before our hand arrives at the object. According to studies in other primates the representation of space in the parietal cortex is not organized into a single map like the retinotopic map primary visual cortex. Instead it is divided into four areas that also have direct connection to the spinal cord. Voluntary movements are controlled by descending signals from several cortical areas. For this reason, the task of generating limb movements is thought to be broken up into multiple subtasks, each managed in parallel by one of the several cortical motor areas. In macaques the two areas on the lateral surface of the frontal lobe are the lateral ventral premotor area and the lateral dorsal premotor area. The ventral premotor cortex mostly controls mouth and hand movements. Most of its neurons do not discharge in association with simple movements toward an object. They only become active during goal-directed actions such as grasping, holding, or manipulating an object. The two areas in macaques on the medial surface are the supplementary motor area, which lies in the medial wall of Brodmann's area 6, and the cingulate motor area, a group of motor areas buried in the cingulate sulcus. Similar premotor areas also exist in humans, but differences in size and sulcal patterns make it difficult to identify homologous areas with precision. Vision for action also seemed to be triggered by relevance, familiarity and other higher cognitive processes (Jacob & Duffy, 2015). These authors found that the neurons in the MSTd (dorsal medial superior temporal area) of the rhesus monkey fired in response to unexpected shift-movements of the head for relevant locations and stimuli. Meaning that movements are not simply a reflex arc controlled by cortical sensorial-motor connections. Primates have remarkable visuomotor capacities. We can link the sight of an object with quite different actions. An apple can be eaten, or thrown at someone, or sliced and become an apple pie.

1.1.4 Visual perception

(Reviewed in Snowden, 2006; Kandel, Schwartz & Jessel, 2013)

A key feature of human visual perception is stereoscopic vision or our ability to see in 3-dimensional space. It happens because we humans have two eyes separated by 6 cm, so the visual primary cortex has the task to overcome two different inputs from a visual scene, resulting in perception of depth and distance. The interocular distance is key to the perception of depth, and the central point that is called the fixation point and the visual system calculates the distance of an object in relation to the fixation point. Any point in the object we are seeing that is nearer or farther than the fixation point is projected at some distance of the center of the retina. The convergence of our eyes causes that fixation point to fall on identical portions of each retina. When we stare our gaze at some object, the proximal or distal points to the fixation point produce binocular disparity by stimulating slightly different parts of the retina on each eye and perception on depth and distance is produced from this.

Besides 3-dimensional vision, our brain has the task to organize how visual features are discriminated in a scene in low, intermediate, and high levels. Low level discrimination assesses visual characteristics such as local contrast, orientation, color and movement. The intermediate level, involves analysis of the layout of scenes and surface properties, parsing the visual image into surfaces and global contours, and distinguishing foreground from background. The highest level involves object recognition because it is the link between vision and cognition.

Ocular dominance is the measure of the relative strength of input from each eye; It varies from person to person. Ocular dominance columns reflect the retinotopic map of LGN because they keep the segregation of thalamocortical inputs from the hemiretinas, maintaining the ipsilateral and contralateral organization in V1. Is worth to remember that organization of V1 at the cell level, perfectly resembles the visual field. This organization is columnar with similar functional properties such as orientation, specificity and the integration of inputs from the two eyes.

The inferior temporal cortex (ITC) is the end of the ventral or What pathway, is the most important area for object recognition and is a place of convergence for other connections that are reciprocal such as the medial temporal lobe and the prefrontal cortex because aside from object recognition, the inferior temporal cortex is involved in higher functions such as recognition of complex forms. The ventral visual stream adapts visual information into a conscious representation of the world; responsible for our perception.

1.1.5 Visual attention: Explicit and Implicit.

Perception is a complex process that integrates neuronal mechanisms such as attention and consciousness (still one of the great unresolved problems in neuroscience). An important step in understanding perception is the selective filtering of visual information that is achieved by visual attention. The main areas involved in visual attention according to studies in awake primates are the superior colliculus and striate cortex. Visual attention facilitates coordination between the two separate visual pathways.

Attention is the process by which the brain controls and tunes information processing; in the case of visual attention it involves saccadic movements in the eye. According to Tsotsos, (2011) “Attention adapts the visual system to its dynamic needs that are dictated by current input and task so that it may perform as well as possible within its capacity”. Positron emission tomography (PET) measurements have found that the parietal lobe is deeply involved in attentional tasks; this fits the data with patients. Attention can be divided between explicit and implicit. Explicit attention is driven by knowledge and expectation and involves saccadic movements in the eye. It can be also called voluntary attention and is closely linked to saccades because the fovea has a much denser array of cones than the peripheral retina and this permits a finer-grain analysis of objects than is possible with peripheral vision. (Rao et al., 1996; Posner, 1980; Schall & Thompson, 1999).

Because the fovea is the area where we can have a clearer image, attention is being linked to a faster object recognition during the explicit or voluntary kind of attention. Implicit attention involves detection through sensorial cues, such as color salience. This concept of covert/ implicit attention was first introduced by Helmholtz in 1896 and summarizes the ability to attend to different portions of an image on the retina without eye movements.

Attention, both voluntary (explicit) and involuntary (implicit) has several measurable effects on human visual performance: It makes perception more sensitive and it shortens reaction time when decision making. This increased sensitivity includes the ability to detect objects at a lower contrast and ignore distracters close to an object. Explicit can be explained as a top-down process and implicit as a bottom-up process (Posner, 1980; Tsotsos, 2011).

From visual search experiments, we seem to have identified two mechanisms of attention-first, a pre-attentive process extracts simple features from the scene (such as colors and oriented line segments). A second process- focal attention- then appears to perform further processing on these items (Neisser, 2014).

1.2 Categorization of objects in the brain.

Object representation is a higher-level visual task. This means, that both sensory information and cognitive processes are needed. The question of how we perceive our outside world as “reality” is still a debate but, according to Kandel, Schwartz & Jessel, (2013) is defined as “the resulting generalization of the numerous retinal images that is also combined with sensory modalities, attaches emotional valence, and associates the object with the memory of other objects or events”. For example, our object representation of a cookie can be stored in working memory and associated with memories of many different types of cookies. This can trigger different memories associated with the cookies (going to grandma’s), and can also be recalled when needed or wanted. The ITC plays a key role in this process.

Another aspect of the visual human experience is categorical perception, which is the ability to mask certain characteristics of an object when we need to treat them as the same. For example, we know an object is an apple even when it might be of different colours (red, yellow) or some more round than others. Categorical perception helps us perceive our world in terms of the pre-existent categories we have formed through experience.

Visual search, another important characteristic of the visual experience, is intimately related to an object’s features such as colour, orientation, and shape. So, to pick out the mushrooms in your pizza amongst the onions, green peppers, tomatoes, and meats requires an active visual scan, very related to eye movements and attention. All of this makes our behavior efficient, so we can accurately recognize an object and function in the world.

1.2.1 Clinical observations: agnosias.

Visual processing can be disrupted according to damage in a specific cortical area. For example, patients that have damage to the ITC show failure to recognize objects. The most common defect in clinical observations is visuospatial neglect. Patients with visuospatial neglect do not respond to objects presented in the visual field contralateral to the parietal lesions (more common after right parietal damage). This happens despite the patient not having a blind spot or scotoma or damage to the striate cortex. Also, patients with lesions in the ITC frequently have difficulty in discriminating different forms and have poor visual memory for forms. "Agnosias" from the Greek that means "lack of knowledge" described these clinical observations, that can be quite selective, for example, a patient may have a selective inability to perceived depth but everything else is spared.

Kandel, Schwartz & Jessel (2013) described two basic categories of visual agnosias: apperceptive and associative. In Apperceptive Agnosia patients are unable to match or copy complex visual shapes. This defect is the result of damage in the first stage of object recognition: integration of visual characteristics into sensory representations of entire objects. On the contrary for Associative Agnosia patients are able to match or copy objects, but they cannot recognize them. In associative agnosias the second stage of object recognition is impaired: association of the sensorial representation of an object with knowledge of the object's function. A very interesting type of associative agnosia is related to food and I describe it in the following section.

1.2.2 Visual attention for food and no food.

From the evolutionary perspective it is argued that the information in the brain is represented in categories that ensures survival and fitness of individuals (Spence et al., 2016). As such, brain damage could lead to category specific agnosias such as the inability to recognize or understand the function of food. It could be very specific to natural food (i.e. fruits and vegetables), or living things (i.e. animals, flowers, or plants), while knowledge about non-living things (i.e. tools, furniture, means of transportation) remains less affected.

The case of food agnosias has been reported in many case studies: Patients I.N.G., J.B.R, K.B., and S.B.Y described by Warrington and Shallice (1984), patient L.A. (Gainotti & Silveri, 1996), S.B. (Sheridan & Humphreys, 1993) and Felicia (De Renzi & Lucchelli, 1994) all showed the same deficit: they could not name food or animals, but they were fine repeating tool's names. Also, bizarre behavior such as eating raw potatoes and frozen food was reported in these patients. Another similar case, M.U. (Borgo & Shallice, 2003) responded poorly to all the lexical-semantic tasks that involved natural and processed foods, liquids, and animals, but tasks naming tools were normal. An interesting case by Yasuno et al., describes the behavior of a professor (60 years old, right handed, male) who after a cerebrovascular accident was impaired in naming and categorizing fruits and vegetables only (answering only 6 of 20, versus 53 of 60 for other categories). This highly selective category agnosia for food does not appear to fall with other dichotomies, such as living/non-living (Yasuno et al 2015).

In the real world, outside of the laboratory setting and protocols, people see their food when they are eating, visual processing is an essential step in the process of eating. The understanding of the neural principles of eating should include the basic visual processing of food cues.

There are many hypotheses about how brain areas process food cues. It is defended by the grounded cognition theory that seeing a picture of food activates similar areas as actually consuming the food. In other words, we have a whole system that anticipates the likelihood of eating experiences associated with perceived food cues (Chen et al., 2016). In general, there is widespread brain activation associated with processing food cues (Chen et al., 2016). These include: the fusiform gyrus (part of the occipital and temporal lobe) and the inferior temporal gyrus (both involved in the visual processing of foods), insula and frontal operculum (food taste), orbitofrontal cortex (OFC; that has to do with reward), amygdala (gives attentional salience), inferior frontal gyrus (eating behaviors), parietal cortex (body image), and striatum (food reward). The integration of these different inputs that are associated when the food cue is seen, produce an overall approach or avoidance tendency (Kaye et al 2013, Chen et al 2016).

Our modern society is full of food marketing like never before. We also have access to a wide variety of food. Understanding the neural and behavioural underpinnings of food object recognition can be crucial to understand obesity and other eating disorders. According to Spence et al. (2016), a “food-cue” is any information associated with a particular kind of food that is capable of activating cognition about it without eating it.

With respect to behavioral experiments, it has been shown that participants react faster to images of food objects versus other types of objects. Specifically, in a visual search task, participants show an advantage (faster reaction times) to food pictures over kitchen utensils, animals, or cars (Nummenma et al. 2011, Sawada et al. 2017). Calorie content and vision recognition seem related. Using high calorie food pictures versus low calorie food pictures Toepel (2009) found that participants not only had enhanced neural responses (using EEG) in reward related brain regions (e.g. striatum) but reaction time was also faster for high-caloric food.

1.2.3 Obesity and food visual recognition.

Visual food processing has been linked with obesity. The right brain hypothesis (Alonso-Alonso, 2007) proposes that activity in the right prefrontal cortex and inferior frontal gyrus is disrupted in obese patients. They suggest that these patients have deficits with self-regulation cues. Using transcranial magnetic stimulation (TMS) on these particular brain areas improved self-regulation behaviors (greater adherence to a diet plan), which highlights the importance of the right prefrontal cortex in executive control. Another explanation of how visual processing of foods is linked to obesity is the "incentive sensitization theory of obesity" (Nijs and Franken, 2012). Brain imaging studies show that obese people have hyperactivation of the brain regions involved in taste and reward (ventral striatum) and this taste and reward response is triggered by anticipatory visual cues. In other words, the visual cues related to food trigger a greater response in the reward centers (Devoto et al., 2018). Several lines of research (e.g. molecular genetics) are now looking into how cognitive processes are changed in obesity. Lately, Vainik et al., (2018) have link visual attention for food cues in the environment as a key feature of a cognitive profile for obesity.

1.2.4 Reaction time in the context of vision.

Reaction time is the interval of time between the onset of a signal (stimulus) and the initiation of a movement response. For purposes of my thesis I assume that reaction time is the result of a perceptual bias influenced by attentive processes that suggest a sensitivity to detect certain objects. If a faster reaction time is produced by a particular stimulus I will assume that such stimulus engaged the participant's attention to a greater degree than a slower-to-respond to stimulus.

1.3. Continuous Flash Suppression.

During the time we are awake, our brain accumulates more sensory information that we can process, so only a small selection of this input gets to consciousness. This is possible because beyond V1 cells have equal input from the two retinas and are not able to differentiate which eye is stimulated (Crick and Koch, 1998). An intriguing phenomenon, particular of human vision is utrocular perception, where in complete darkness with having a light shining in one eye, we are unable to tell which eye was stimulated. The notion that something gets into one retina and it is processed in V1 but a person reports not knowing exactly which eye got stimulated is a line of inquiry. Then, a way to study consciousness in neuroscience is binocular rivalry. In this technique, a simple image (for example a pattern of horizontal lines) is shown to the left eye, while a different pattern is shown (e.g. straight lines) to the right eye. This technique results in one of these patterns being suppressed intermittently for a few seconds. So even though the inputs were the same and steady reflecting to both retinas, one of the objects achieved consciousness while the other did not. In macaques, a series of studies (Leopold & Logothetis, 1996) found that cells in V1 have little involvement in the percept of binocular rivalry; it is the cells in the IT cortex and structures in the ventral visual pathway that fire for the image that the animal reports to see. In fMRI experiments the same pattern is found; there is more hemodynamic activity in the upper stages of the ventral pathway for the responding stimulus when compared to the suppressed one (Rees, 2007).

One step ahead of binocular rivalry is called continuous flash suppression (CFS; Tsuchiya & Koch, 2005). While in the traditional binocular rivalry paradigm, the two displays of equal "potency" (e.g. comparable motion content and luminance contrast) are presented to each eye, CFS critically saturates one eye while showing an image to the other. The saturation of the first eye (usually the dominant eye) comes from flashing contour-rich patterns of high contrast (Mondrians), while the other eye is presented with a stimulus that is typically stationary and of moderate contrast. The flashing pattern saturates one eye and causes a time range (up to 12 seconds) where the other stimulus is invisible.

There are at least three different paradigms used in CFS: Adaptation aftereffects, in which exposure to a stimulus give rise to visual aftereffects by showing one object of a precise category to one eye (e.g. male face) while showing the flashing mondrian to the other. Then a subtle difference in the image is introduced (e.g. female face) at the end. The test is to recognize the original image among other similar images that were presented. This paradigm has been widely used in psychophysics studies to isolate and test the neural mechanisms involved in how we process specific features of categories (e.g. facial emotion). The second paradigm is priming effects. This technique involves presenting objects of the same category as the target but before presenting the target during CFS. For example, priming of mammals would utilize horses, cows, and cats, before presenting dogs as the target stimuli under CFS. The prime should share some characteristics of the target object (Yang et al, 2014). The idea is the prime is registered without consciousness and influences the identification of the target object.

1.3.1 What is b-CFS? Conscious and unconscious bias.

The third paradigm is the one of interest for this thesis, and it is called breaking continuous flash suppression (b-CFS). b-CFS is based on the time it takes a person to break suppression and consciously perceive the target. This technique is different from adaptation and priming paradigms because in b-CFS the suppressed stimuli or its category have not been presented in any form before (Yang et al., 2014). Using this technique, studies have found that faces with signs of fear tend to break suppression faster than other facial expressions, as do faces with eyes fixed directly at the observer (Yang et al., 2014). Also, using b-CFS it has been shown that images of morphemes (i.e. the smallest grammatical unit in a language) that are part of a person's native language break suppression faster than morphemes in another language (Costello et al., 2009). This paradigm is used for investigating perceptual and higher-level cognitive processes. One of the key features that drew me to use this paradigm in my thesis, is that b-CFS relies on the notion that unconscious processing is unprompted and involuntary. Although the target object is suppressed for a few seconds, it is still being processed by familiarity, meaning, and emotional link. (Alpers & Gerdes, 2007; Yang et al., 2014).

To date there has not been a completely established protocol to measure awareness. To complicate matters more, there are many examples where awareness is denied by a participant, but the behavior demonstrates that the information was processed. Cortically lesioned patients often deny having awareness of visual stimuli presented to their blind field but can successfully perform objective tasks towards those stimuli (De Gelder et al., 2008). This has also been shown in healthy individuals, where they have similar dissociations (Kolb and Braun, 1995; Lau and Passingham, 2006). For example, visual illusions in healthy participants will not affect reaching and grasping but do affect these processes when participants have to make a recognition or estimate about the objects (Goodale et al., 2008). On the other hand, objective and subjective measures of awareness are not only dissociable at the behavioral level but neurally too. Hesselmann et al. (2011) used b-CFS to demonstrate that activation in early visual areas correlate with the report of localization of the Mondrian, whereas activation in secondary visual areas correlate with the rate of the visibility of the emergent stimuli.

About the relationship between CFS and attention; Yang et al. (2014) proposed that one function of attention before awareness is “to temporarily bind the encoded features of an invisible stimulus to create high-level representations that guide behavioral and perceptual processes outside of awareness”. Specific characteristics of the object may drive awareness for the location of the object, even when suppressed. The role of attention may be to drive awareness, highlighting or debilitating the neural signals associated to those features from the suppressed stimulus.

An explanation of why some objects have a preference to break suppression faster during b-CFS paradigms, is that vision has evolved to ensure fitness and survival of organisms. Structures involving the dorsal visual pathway are active even without the report of visibility for highly relevant objects (e.g. manipulative objects), meaning processing information still happens on suppressed stimuli (Fang and He, 2005).

I proposed in this thesis that there is a pre-attentive advantage for food items, outside of awareness, similarly to how tools and emotional faces are processed pre-attentively by the dorsal and ventral visual pathways.

1.3.2 Object manipulation type influences on vision (precision vs. whole hand).

In line with the previous paragraph, there are objects that are more relevant for survival than others. Arguably, objects that a person can grasp and manipulate (a food item) are more important than those that are just pleasant to the viewer (e.g. nice sunset). Recent fMRI studies highlight the importance of object manipulation during silent object naming by demonstrating activation of areas of the cerebral cortex thought to store information about motoric actions associated with the movement (Chao & Martin, 2000). Cortical areas that are specifically activated during the identification of manipulable objects include the left ventral premotor and left posterior parietal cortices (dorsal stream structures). Filliter et al., (2004), carried out a study in which they controlled for object manipulability and familiarity. Using pictures of living vs. non-living categories the authors demonstrated advantages for the identification of manipulable living objects. Interestingly, these authors used fruits and vegetables as the stimuli for the manipulable living objects. To study manipulability in food and no food objects, I considered whole hand objects as the ones are more likely graspable by our entire hand (most of the fingers and palm), while precision grasp objects where the ones we humans (and other primates) grasp with our thumb and index finger.

1.4 The Problem.

The evolutionary relevance of food objects is hypothesized to give them a pre-attentive advantage in comparison to other objects. But, findings are controversial, a visual search paradigm for food has shown conflicted results between food and other objects and yet no pre-attentive food advantage is reported in any paradigm. It seems clear that calorie content is important, but it is not clear what aspect or categories of food objects could affect their detection. Processed state: nature-made (e.g. raw fruits and veggies) versus processed (e.g. pizza, hamburger) and type of grasp: precision (e.g. to pick up a cherry) versus whole hand (e.g. to pick up an apple)) are usually not considered, even though these are fundamental characteristics of the objects encountered every day. The purpose of my thesis therefore, is to assess if there is an advantage (faster reaction times) for food, for the process state, and for manipulability of objects. Furthermore, I investigate if an advantage exists with and without awareness using b-CFS and a control version of b-CFS (No b-CFS) as a protocol. I used pictures of Food and No-Food items divided in these categories: Nature, Processed, Whole hand-grasp and Precision (see figure 4). These different aspects surrounding a food object could affect our perception, such as Nature and Processed objects which we know are processed differently by the brain (e.g. food agnosias). Manipulability could also affect the reaction time by pre-attentive information accessing the dorsal and ventral streams differently.

Assumptions: The studies conducted in this thesis were based on two assumptions: 1) That reaction time is a measure of visual attention, thus shorter reaction times to a given stimulus suggest that preferential attention was given to that stimulus; and 2) that the b-CFS technique would yield a measure of how long it takes to the brain to processes a stimulus from the pre-attentive to the attentive state.

The hypotheses and predictions are described next and a brief description of each experiment is included below.

1.4.1 Hypothesis and predictions

Hypothesis 1: There is an advantage in the visual detection of Food objects in both the pre-attentive and attentive stages.

Prediction 1: If there is a visual advantage for Food objects at both levels of attention, shorter RTs for Food objects compared to non-Food should emerge in all conditions.

Hypothesis 2: There are two other variables (Manipulability and Process state) affecting the visual attention for Food objects.

Prediction 2: If Process state and Manipulability of Food objects play a role in their detection, RT differences should emerge between Nature- and Processed objects, and between Precision- and Whole hand-grasp objects.

Based on these hypotheses, four experiments were designed.

1.4.2 Experimental Design

Study 1: **Explicit No b-CFS** (control). Healthy participants were asked to respond to whether an image presented on a screen was Food or not Food by pressing one key for Food and another key for not Food using a keyboard. In this condition there is no suppression induced by the Mondrian since the flashing occurs at the same time for both eyes. The target slowly moves from the background into the foreground (Korb et al., 2017).

Study 2: Implicit No b-CFS. Healthy participants were asked to respond if an image presented on a screen was located on the right or the left side of the computer monitor. We introduced this implicit condition in order to test if making Food irrelevant would affect reaction times. Just like in study 1, in this condition there was no suppression.

Study 3: Explicit b-CFS. Healthy participants were asked to respond if an image presented on a screen was Food or not Food by pressing one key for Foods and another key for not Food using a keyboard. I used b-CFS protocol similar to (Korb et al., 2017) using Psychopy (Python) in which the image of an object is masked by the flashing Mondrian (see more details in the methods section).

Study 4: Implicit b- CFS. Healthy participants were asked to respond if the image was presented was located on the right or the left side of the computer monitor. The same b-CFS protocol used in Study 3 was used here.

2. Methods and Materials

2.1. Study 1: Explicit No b-CFS

2.1.1. Participants

Fifty-seven university students (16 males and 41 females) participated in the study in exchange for course credit. All participants were right handed and had healthy eye sight. Handedness was assessed using a modified version of the Edinburgh (Oldfield, 1971) and Waterloo (Brown et al., 2006) handedness questionnaires. Mean age was 24.3 years old +/- 2.8, BMI (Body Mass Index kg/m^2) 23.294 +/- 4.33. Binge Eating Scale (Gormally et al., 1982) score mean 8.54 +/-3.08, Eating Attitudes Test (Garner et al., 1982) 7.3 +/- 6. The BMI for Females was 22.55 +/-5.3 , Males 22.75 +/-10.29.

2.1.2. Materials and Procedure

Both experiments were run on a iMac with stimuli presented on a 54.61 cm screen at a resolution of: 1280 x 800 pixels and a refresh rate of 60 Hz. Stimulus (See Figure 4) presentation was controlled by PsychoPy Experiment Builder (v1.82.01).

Before starting the experiments, eye dominance was tested for each participant using the Miles Method (Miles, 1929). Subjects form a small window by interlocking their hands to create a triangle. Then they move this window closer and closer to their face without losing sight of the examiner’s thumb. The eye chosen to look through the window is known to be the dominant one. The participant was then seated 60 cm in front of the computer, and a chin-rest and chair were adjusted for participant height and comfort. Participants were given a pair of prism glasses (see below) to wear.

Prisms: A pair of eyeglasses (10/10 Base Out B.O. lens correction for image displacement) emulated stereoscopic vision. Two square picture frames were present on the screen (420 x 420 pixels), 400 pixels apart with a 60 cm divider across the center of the screen. When the prism glasses were put on, alignment was adjusted if necessary for each participant to ensure a complete overlap in the visual field for both frames (10° medial shift). Stimuli (opacity 0.6, size: 190x190 pixels) were presented to both frames in a randomized quadrant with the high-contrast mask (Mondrian) as a background.

Procedures. Each experiment consisted of 10 blocks of 30 trials, and one block of 20 trials, for a total of 320 trials altogether (see Figure 4 and Appendix 1). Breaks were given between each block. Before starting the task, participants were instructed to press the key 'F' if the picture that was going to be presented (inside a square frame 25.4 x 25.4 cm) was that of a Food object or the letter "J" if it was not a Food item. If they saw no image at all, they were told not to press any keys. The participant was instructed to use their right or left index finger on the keyboard depending on the block number during the experiment (randomized between participants). In addition, participants were asked to keep their gaze focused on the fixation cross on the center of the screen for the duration of the task (excluding breaks).

Stimuli

Eighty stimuli in total were selected from the FRIDa database (Foroni et al., 2013). All stimuli were considered 'Manipulable' objects. Of those 80 stimuli, 40 were considered Food, and 40 were considered Not Food objects. Within each of those categories, 20 were considered natural items, and 20 were processed (any food or object that has been manipulated from its original state by a human and is no longer present in its natural state). Lastly, each of those categories was further broken into 10 precision grasp objects, and 10 whole hand grasp objects. Precision grasp objects are those that can be picked up between the second digit and thumb. Whole hand grasp objects are those that would use all five digits during a grasping movement. Objects such as tools, or items with an elongated axis or handles were avoided in order to prevent any bias in RT as studies have found that this type of object produces faster reaction times (Almeida et al.,2010; Sakuraba et al., 2012). Images were matched for spatial frequency and luminance to make sure there were no significant outliers.

In the no b-CFS the target object is presented in both picture frames (instead of just in one as in b-CFS). The object thus is presented to both eyes but begins by being hidden completely by the flashing picture of the Mondrian. The target moves from the background to the foreground at 16 Hz simultaneously in each frame; so, the target picture is still until the participant presses a key or until 10 seconds has elapsed.

2.1.3. Analyses

Data were expressed as RT in seconds. A repeated measures ANOVA was assessed in SPSS 24 with: Food (Food vs. No Food), Manipulability (Whole hand Grasp vs. Precision) and Process State (Nature vs. Processed) as within factors.

2.2. Study 2: Implicit No b-CFS

2.2.1. Participants

Twenty-seven university students (9 males and 18 females) participated in the study in exchange for course credit. All participants were right handed and had healthy eye sight. Handedness was assessed using a modified version of the Edinburgh (Oldfield, 1971) and

Waterloo (Brown et al., 2006) handedness questionnaires. Mean Age 20.7 years +/- 2.4, BMI 24.36 +/- 4.63. Binge Eating Scale (Gormally et al., 1982) score mean 9.62+/-5.08, Eating Attitudes Test (Garner et al, 1982) 6.66 +/- 8.19.

2.2.2. Materials and Procedure

Similar materials and procedures to those from Study 1 were used in this study. The only difference was that participants were asked to respond to the side of the screen on which the target stimuli were presented (i.e. right or left) by pressing the “F” or “J” keys on the keyboard.

2.2.3. Analyses

Similar analyses to those of Study 1 were used for this study.

2.3. Study 3: Explicit b-CFS

2.3.1. Participants

Twenty university students (6 males and 14 females) participated in the study in exchange for course credit. All participants were right handed and had healthy eye sight. Handedness was assessed using a modified version of the Edinburgh (Oldfield, 1971) and Waterloo (Brown et al., 2006) handedness questionnaires. Mean Age 23.2 years, BMI 23.81 +/- 3.12. Binge Eating Scale (Gormally et al., 1982) score mean 12.31 +/- 5.32, Eating Attitudes Test (Garner et al, 1982) 6.4 +/- 5.74.

2.3.2. Materials and Procedure

Similar Materials and Procedure to those of Study 1 were used for this study.

Prism glasses. Stimuli (opacity 0.6, size: 190x190 pixels) were presented to one frame in a randomized quadrant, while the high-contrast mask (Mondrian) changing at a rate of 16 Hz, was presented to the other. These two frames would switch at random between each trial, due to the high level of suppression within the task. Each stimulus/Mondrian pair was presented for 10s or until a key response was made before switching.

2.3.3. Analyses

Similar analyses to those of Study 1 were used for this study.

2.4. Study 4: Implicit b-CFS

2.4.1. Participants

Fifty six university students (24 males and 32 females) participated in the study in exchange for course credit. All participants were right handed and had healthy eye sight. Handedness was assessed using a modified version of the Edinburgh (Oldfield, 1971) and Waterloo (Brown et al., 2006) handedness questionnaires. Mean Age 20.9 years BMI 23.59 +/- 4.5. Binge Eating Scale (Gormally et al., 1982) score mean 11.42 +/- 6.62, Eating Attitudes Test (Garner et al, 1982) 7.8 +/- 6.95.

2.4.2. Materials and Procedure

Similar Materials and Procedure to those of Study 1 were used for this study.

2.4.3. Analyses

Similar analyses to those of Study 1 were used for this study.

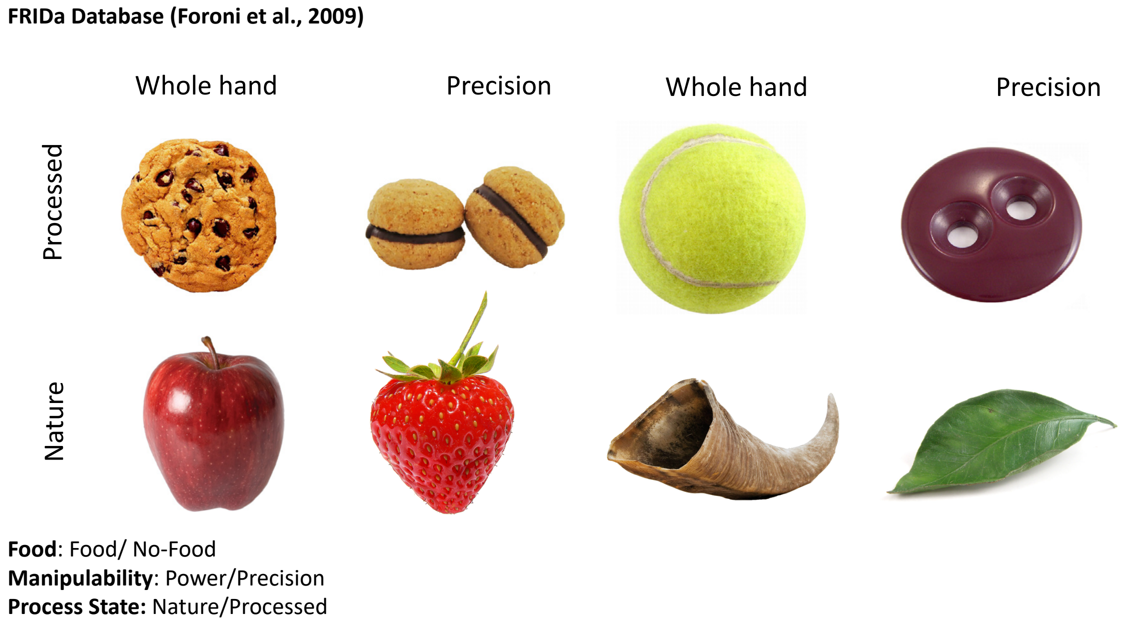


Figure. 4 Examples of figures retrieved from FRIDa Database proposed by Foroni et al., (2009), every image is controlled for low visual features (contour, color, brightness, size)

3. Results

3.1 Analysis one: No b-CFS Explicit

There was a main effect of Food [faster RTs for Food; F(1,56)=11.704, p=.001]) see Table 1 for means and standards deviation, no main effect of Manipulability [F(1,56)=3.108, p=.083] and a significant main effect of Processed state, [faster RTs for Processed stimuli; F(1,56)=6.785, p=.012]. All the possible interactions were significant, including the 3-way interaction of Food*Manipulability*Process state [F(1,56)= 6.549, p=.013]. Follow up analyses (separate ANOVAs for Food versus no-Food) revealed that the 3-way interaction was because (see Figure 5) for the Food stimuli the Manipulability*Process state was significant (F(1,56)= 26.211 p=0.000) but this was not the case for the No-Food stimuli (F=1.528, p=.220). Foods that could be picked up with a whole hand grasp and that were processed were the fastest to elicit a response.

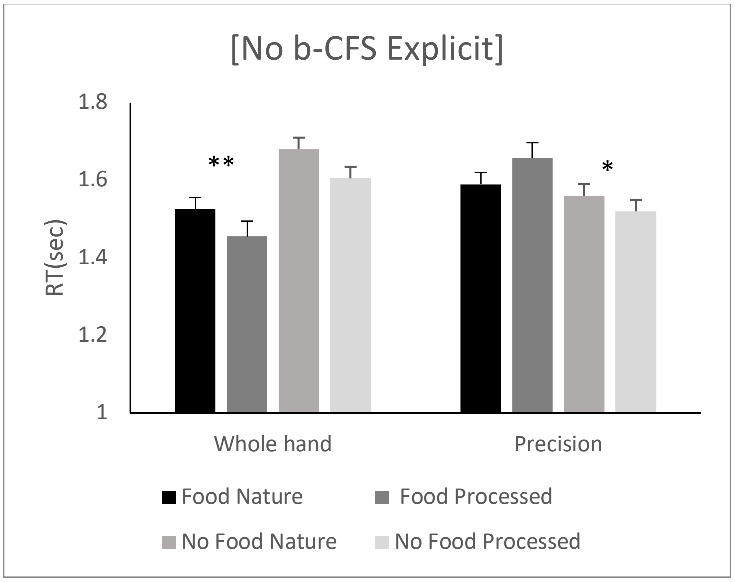


Figure 5. Results No b-CFS Explicit 3 way interaction.

The interaction comes from objects that are manipulable with the whole hand are significantly faster to detect than precision food objects, while in the no food condition objects that are manipulable with precision-grasp are faster to detect than whole hand.

3.2 Analysis two: No b-CFS Implicit

There was a main effect of Food [faster RTs for Food; F (1,26) = 6.296, p=.019)], (see all means and standard deviations in Table 1), a significant main effect of Manipulability [faster RTs for Precision; F (1, 26) = 14.453, p=.001] and a significant main effect of Process state [faster RTs for Nature objects; F (1, 26) =7.671, p=.010]. All the possible interactions were also significant, including the 3-way interaction of Food*Manipulability*Processed state [F (1,26) =15.472, p=.001]. Follow up analyses (separate ANOVAs for Food versus No Food) revealed that the 3-way interaction was because (see Figure 3) just like in the Explicit condition, in the Food stimuli the Manipulability*Process state was significant (F(1,26) = 54.772 p<0.000) but this was not the case for the No Food stimuli (F(1,26) =.159 p=.693). Foods that could be picked up with a whole hand grasp and that were processed were the fastest to elicit a response.

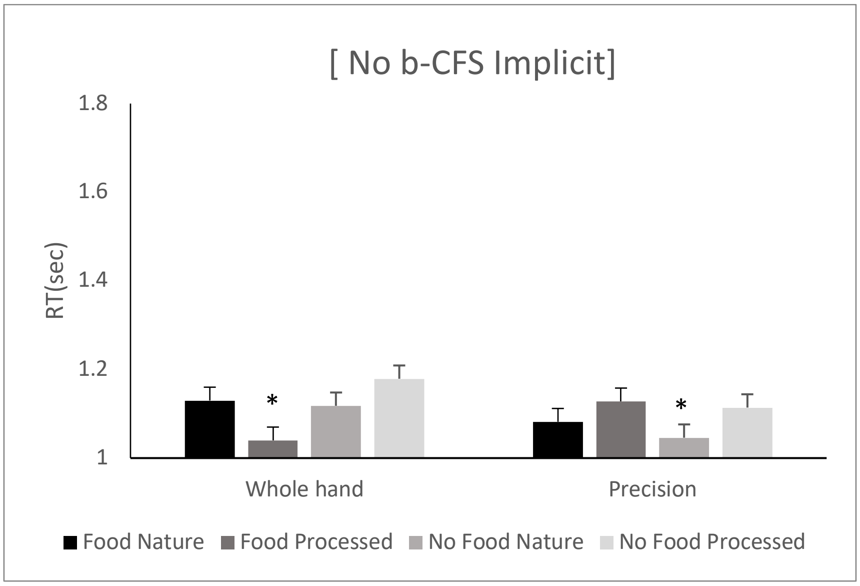


Figure 6 No b-CFS Implicit 3-way interaction.

All the reaction times are significantly faster than the explicit condition. The same pattern was found, food that can be grasp with the whole hand and processed are faster. While the opposite happens with the no food category, precision grasp nature objects are the ones that are faster.

TABLE 1. No b-CFS Explicit and Implicit

Descriptive Statistics

		Mean	Std. Deviation	N
Explicit	Food Whole hand Natural	1.525714	0.231515867	57
	Food Whole hand Processed	1.455433	0.249338788	57
	No Food Whole hand Natural	1.680321	0.298271714	57
	No Food Whole hand Processe	1.605167	0.249474595	57
	Food Precision Natural	1.590394	0.282066416	57
	Food Precision Processed	1.656862	0.296639225	57
	No Food Precision Natural	1.559507	0.272658448	57
	No Food Precision Processed	1.520353	0.263536935	57
Implicit	Food Whole hand Natural	1.129554	0.192726726	27
	Food Whole hand Processed	1.040347	0.164003918	27
	No Food Whole hand Natural	1.118245	0.191990042	27
	No Food Whole hand Processe	1.178613	0.193117772	27
	Food Precision Natural	1.081857	0.190403077	27
	Food Precision Processed	1.127865	0.205825641	27
	No Food Precision Natural	1.046049	0.181020805	27
	No Food Precision Processed	1.114131	0.191564814	27

Food

Food		Mean	Std. Error	95% Confidence Interval	
Explicit	Food	1.557	0.033	1.49	1.624
	No Food	1.591	0.034	1.524	1.659
Implicit	Food	1.095	0.035	1.022	1.168
	No Food	1.114	0.036	1.041	1.187

Manipulability

	Manipulability	Mean	Std. Error	95% Confidence Interval	
Explicit	Whole hand	1.567	0.032	1.503	1.63
	Precision	1.582	0.035	1.512	1.652
Implicit	Whole hand	1.117	0.035	1.045	1.189
	Precision	1.092	0.036	1.019	1.166

Process State

		Mean	Std. Error	95% Confidence Interval	
Explicit	Nature	1.589	0.034	1.521	1.657
	Processed State	1.559	0.033	1.493	1.626
Implicit	Nature	1.094	0.035	1.021	1.167
	Processed State	1.115	0.035	1.042	1.188

Food*Manipulability

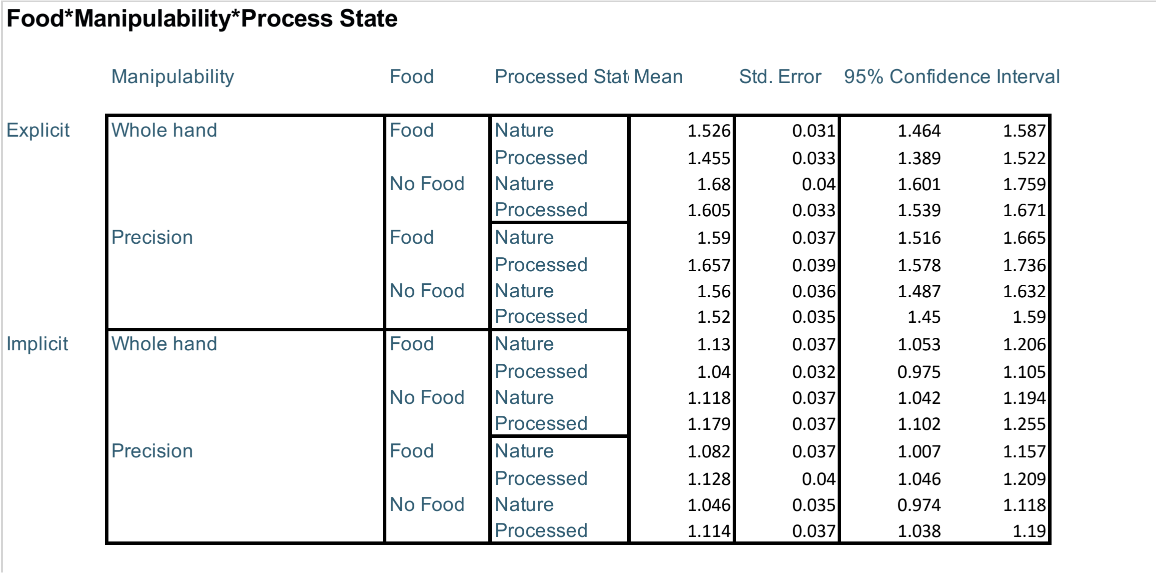
	Manipulability	Food	Mean	Std. Error	95% Confidence Interval	
Explicit	Whole hand	Food	1.491	0.031	1.428	1.553
		No Food	1.643	0.034	1.575	1.71
	Precision	Food	1.624	0.037	1.55	1.697
		No Food	1.54	0.034	1.471	1.608
Implicit	Whole hand	Food	1.085	0.034	1.015	1.155
		No Food	1.148	0.037	1.073	1.224
	Precision	Food	1.105	0.037	1.028	1.181
		No Food	1.08	0.035	1.008	1.152

Food*Process State

	Food	Process Sta	Mean	Std. Error	95% Confidence Interval	
Explicit	Food	Nature	1.558	0.033	1.492	1.624
		Processed	1.556	0.035	1.486	1.627
	No Food	Nature	1.62	0.037	1.546	1.694
		Processed	1.563	0.033	1.498	1.628
Implicit	Food	Nature	1.106	0.036	1.031	1.181
		Processed	1.084	0.035	1.012	1.156
	No Food	Nature	1.082	0.035	1.01	1.154
		Processed	1.146	0.037	1.071	1.222

Manipulability*Process State

	Manipulability	Processed	Mean	Std. Error	95% Confidence Interval	
Explicit	Whole hand	Nature	1.603	0.034	1.536	1.671
		Processed	1.53	0.031	1.468	1.593
	Precision	Nature	1.575	0.035	1.504	1.646
		Processed	1.589	0.037	1.515	1.662
Implicit	Whole hand	Nature	1.124	0.037	1.049	1.199
		Processed	1.109	0.034	1.04	1.179
	Precision	Nature	1.064	0.035	0.993	1.135
		Processed	1.121	0.037	1.044	1.198



Food*Manipulability*Process State

	Manipulability	Food	Processed Stat	Mean	Std. Error	95% Confidence Interval	
Explicit	Whole hand	Food	Nature	1.526	0.031	1.464	1.587
			Processed	1.455	0.033	1.389	1.522
		No Food	Nature	1.68	0.04	1.601	1.759
			Processed	1.605	0.033	1.539	1.671
	Precision	Food	Nature	1.59	0.037	1.516	1.665
			Processed	1.657	0.039	1.578	1.736
		No Food	Nature	1.56	0.036	1.487	1.632
			Processed	1.52	0.035	1.45	1.59
Implicit	Whole hand	Food	Nature	1.13	0.037	1.053	1.206
			Processed	1.04	0.032	0.975	1.105
		No Food	Nature	1.118	0.037	1.042	1.194
			Processed	1.179	0.037	1.102	1.255
	Precision	Food	Nature	1.082	0.037	1.007	1.157
			Processed	1.128	0.04	1.046	1.209
		No Food	Nature	1.046	0.035	0.974	1.118
			Processed	1.114	0.037	1.038	1.19

3.3 Analysis three: b-CFS Explicit

No main effect of Food was found [F (1,19) =2.428, p=.138], nor a main effect of Manipulability [F (1,19) =.325, p=.575], but there was a significant effect of Processed state [faster RTs for Processed items; F (1,19) = 20.663, p=.000)]. Two 2-way interactions were significant: Food*Process State [F(1,19) = 8.965 p=.007] and the Manipulability*Processed State interaction [F (1,19) = 13.874, p=.001]. The Food*Process State interaction was significant because the difference between Nature and Processed was much larger in the No Food stimuli than in the Food stimuli (see Table 2). The Manipulability*Processed State interaction was significant because the difference between Nature and Processed for objects that could be picked up with a whole hand grasp was significant whereas there was no difference between these variables for objects that afforded a precision grasp (see Table 2). The 3-way interaction was not significant [F (1,19) = 2.049, p=.169].

3.4 Analysis four: b- CFS Implicit

No main effect of Food was found [F (1,55) = 1.345 p=.251], a main effect of Manipulability was observed [faster RTs for Precision; F (1,55) = 4.211 p=.045]), but no main effect of Process State [F (1,55) = .001, p=.978]. Two 2-way interactions were significant: Food*Manipulability [F (1,55) =21.158, p=.000], and Food*Process state [F (1,55) = 14.158, p=.000]. The Food*Manipulability interaction was significant because for objects that can be picked up with a whole hand grasp, food items broke suppression faster than no food items. The opposite pattern was observed in objects affording precision grasps (see Table 2). The Food*Process State interaction was significant because processed foods took longer to break suppression than natural foods whereas the opposite was true for no food items (see Table 2). There was no significant 3- way interaction [F=.371, p=.545].

TABLE 2 b-CFS Explicit and Implicit

Descriptive Statistics

		Mean	Std. Deviation	N
Explicit	Food Whole hand Natural	3.1261888	0.935654519	20
	Food Whole hand Man	2.9322615	0.914164886	20
	No Food Whole handNatural	3.3604769	1.140549028	20
	No Food Whole handMan	2.80347095	0.820648638	20
	Food Precision Natural	3.14733755	0.914560425	20
	Food Precision Man	3.23897545	0.922252883	20
	No Food Precision Natural	2.9808466	0.768290608	20
	No Food Precision Man Made	2.9540142	0.919826438	20
Implicit	Food Whole hand Natural	3.107084318	0.781819761	56
	Food Whole hand Man	3.220762223	0.940976093	56
	No Food Whole hand Natural	3.406277529	0.946593043	56
	No Food Whole hand Man	3.188670141	0.755356428	56
	Food Precision Natural	3.188404952	0.889721471	56
	Food Precision Man	3.350064177	0.820189965	56
	No Food Precision Natural	3.082272821	0.801123844	56
	No Food Precision Man Made	3.02047973	0.750725479	56

Food

Food		Mean	Std. Error	95% Confidence Interval	
Explicit	Food	3.111	0.201	2.691	3.532
	No Food	3.025	0.197	2.611	3.438
Implicit	Food	3.217	0.106	3.004	3.429
	No Food	3.174	0.098	2.979	3.37

Manipulability

	Manipulability	Mean	Std. Error	95% Confidence Interval	
Explicit	Whole hand	3.056	0.204	2.628	3.483
	Precision	3.08	0.192	2.678	3.483
Implicit	Whole hand	3.231	0.104	3.022	3.439
	Precision	3.16	0.1	2.961	3.36

Process State

		Mean	Std. Error	95% Confidence Interval	
Explicit	Nature	3.154	0.204	2.727	3.58
	Processed	2.982	0.192	2.579	3.385
Implicit	Nature	3.196	0.105	2.986	3.406
	Processed	3.195	0.099	2.996	3.394

Food*Manipulability

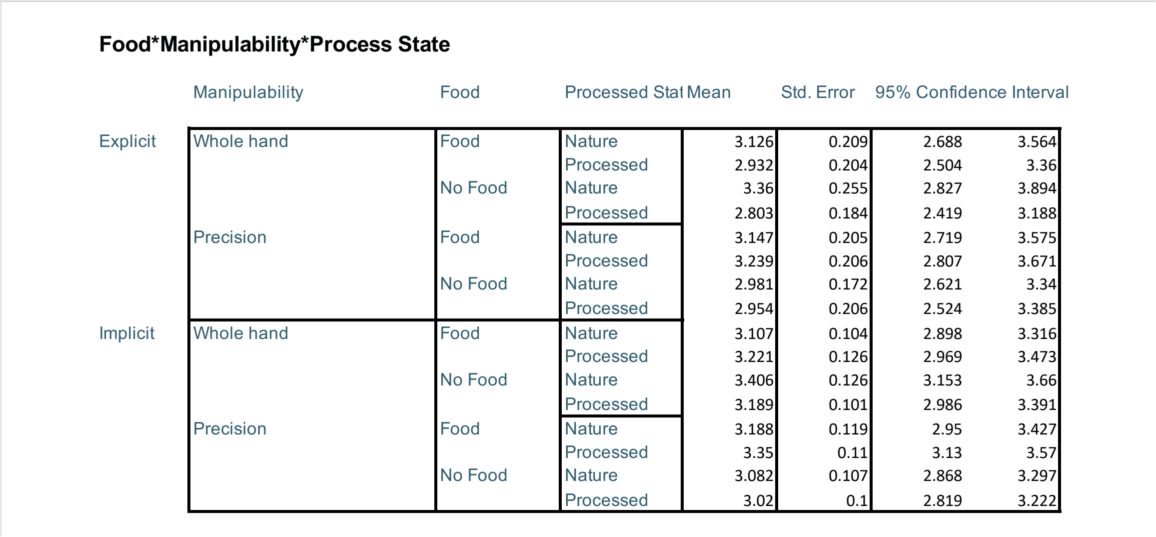
	Manipulability	Food	Mean	Std. Error	95% Confidence Interval	
Explicit	Whole hand	Food	3.029	0.204	2.602	3.457
		No Food	3.082	0.213	2.637	3.527
	Precision	Food	3.193	0.202	2.77	3.616
		No Food	2.967	0.186	2.578	3.356
Implicit	Whole hand	Food	3.164	0.109	2.945	3.383
		No Food	3.297	0.105	3.088	3.507
	Precision	Food	3.269	0.109	3.051	3.487
		No Food	3.051	0.097	2.856	3.246

Food*Process State

	Food	Process State	Mean	Std. Error	95% Confidence Interval	
Explicit	Food	Nature	3.137	0.201	2.716	3.558
		Processed	3.086	0.203	2.66	3.511
	No Food	Nature	3.171	0.21	2.731	3.61
		Processed	2.879	0.189	2.483	3.275
Implicit	Food	Nature	3.148	0.106	2.936	3.359
		Processed	3.285	0.112	3.06	3.511
	No Food	Nature	3.244	0.109	3.026	3.463
		Processed	3.105	0.092	2.919	3.29

Manipulability*Process State

	Manipulability	Processed	Mean	Std. Error	95% Confidence Interval	
Explicit	Whole hand	Nature	3.243	0.229	2.764	3.723
		Processed	2.868	0.184	2.483	3.253
	Precision	Nature	3.064	0.185	2.678	3.45
		Processed	3.096	0.204	2.67	3.523
Implicit	Whole hand	Nature	3.257	0.108	3.04	3.474
		Processed	3.205	0.107	2.991	3.418
	Precision	Nature	3.135	0.107	2.922	3.349
		Processed	3.185	0.099	2.988	3.383



Food*Manipulability*Process State

	Manipulability	Food	Processed Stat	Mean	Std. Error	95% Confidence Interval	
Explicit	Whole hand	Food	Nature	3.126	0.209	2.688	3.564
			Processed	2.932	0.204	2.504	3.36
		No Food	Nature	3.36	0.255	2.827	3.894
			Processed	2.803	0.184	2.419	3.188
	Precision	Food	Nature	3.147	0.205	2.719	3.575
			Processed	3.239	0.206	2.807	3.671
		No Food	Nature	2.981	0.172	2.621	3.34
			Processed	2.954	0.206	2.524	3.385
Implicit	Whole hand	Food	Nature	3.107	0.104	2.898	3.316
			Processed	3.221	0.126	2.969	3.473
		No Food	Nature	3.406	0.126	3.153	3.66
			Processed	3.189	0.101	2.986	3.391
	Precision	Food	Nature	3.188	0.119	2.95	3.427
			Processed	3.35	0.11	3.13	3.57
		No Food	Nature	3.082	0.107	2.868	3.297
			Processed	3.02	0.1	2.819	3.222

3.5 Analysis five: All-together No b-CFS

There was a main effect of Food [faster RTs for Food; F(1,83) = 16.548, , p=.000] (see means and standard deviation in Table 3). No effect of Manipulability [F(1,83) = .147, p= .703], and no effect of Process state [F(1,83) = 2.429, p=.123]. The interaction between Food*Manipulability was significant [F(1,83) = 182.057, p=.000]. RTs for Food objects that could be grasped using a whole hand grasp were faster than for No-Food objects and the opposite pattern was found for objects that afforded a precision grasp (see Table 3). The interaction between Manipulability*Process State was significant [F(1,83) = 31.288, p= .000]. This interaction was because objects affording a whole hand grasp that are processed were faster than nature ones, the opposite was true for objects affording a precision grasp. A significant 3-way interaction between Food*Manipulability*Process state was found [F(1,83) = 14.63 p=.000]. Follow up analyses (separate ANOVAs for Food versus no-Food) revealed that the 3-way interaction was because (see Table 3) for the food stimuli the Manipulability*Process state was significant (F= 51.535 p=.000) but this was not the case for the no food stimuli (F= 1.528 p= .220). Foods that could be picked up with a whole hand grasp and that were processed were the fastest to elicit a response.

TABLE 3. No b-CFS-All together

Descriptive Statistics

	Mean	Std. Deviation	N
Food Whole hand Natural	1.398377031	0.287127926	84
Food Whole hand Processed	1.322012443	0.297328641	84
No Food Whole hand Natural	1.499653951	0.375912266	84
No Food Whole hand Process	1.468060331	0.306329082	84
Food Precision Natural	1.426935575	0.349459387	84
Food Precision Processed	1.486827393	0.366622481	84
No Food Precision Natural	1.394466699	0.344411737	84
No Food Precision Processed	1.389782029	0.307863982	84

Food

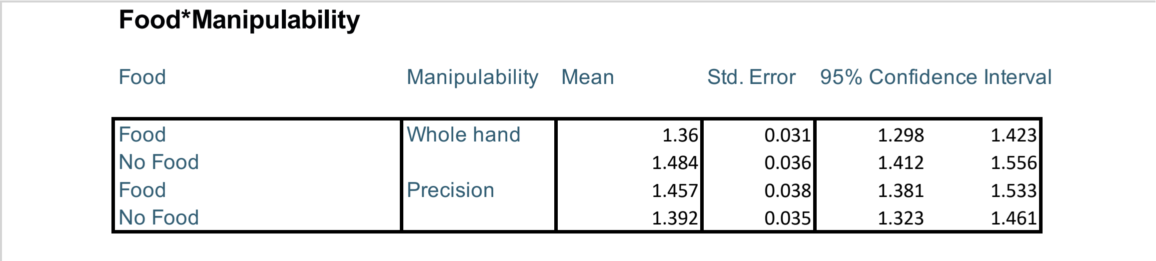
Food	Mean	Std. Error	95% Confidence Interval	
Food	1.409	0.035	1.34	1.477
No Food	1.438	0.035	1.368	1.508

Manipulability

Manipulability	Mean	Std. Error	95% Confidence Interval	
Whole hand	1.422	0.033	1.356	1.489
Pincer	1.425	0.036	1.352	1.497

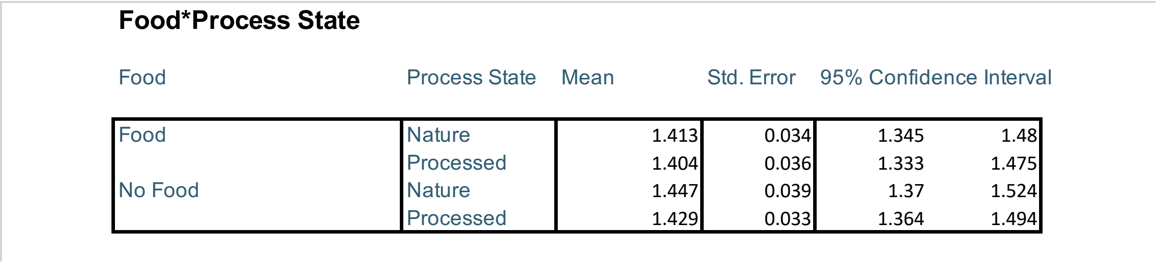
Process State

Process State	Mean	Std. Error	95% Confidence Interval	
Nature	1.43	0.036	1.358	1.502
Processed	1.417	0.034	1.349	1.484



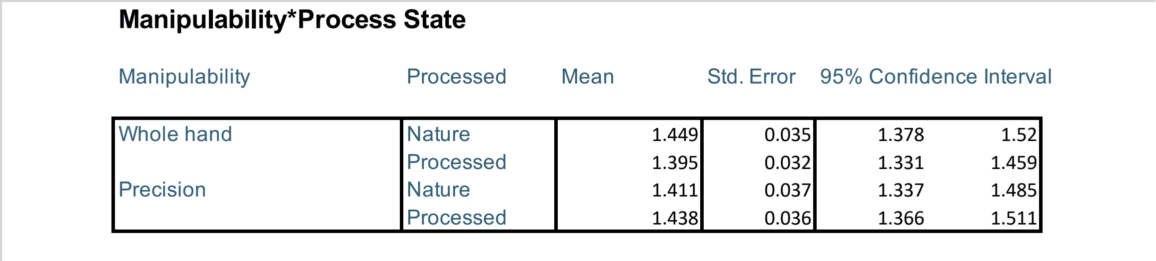
Food*Manipulability

Food	Manipulability	Mean	Std. Error	95% Confidence Interval	
Food	Whole hand	1.36	0.031	1.298	1.423
No Food		1.484	0.036	1.412	1.556
Food	Precision	1.457	0.038	1.381	1.533
No Food		1.392	0.035	1.323	1.461



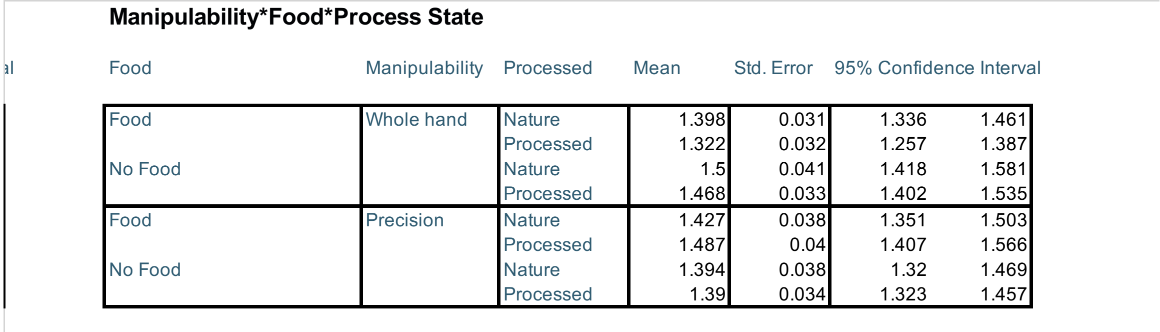
Food*Process State

Food	Process State	Mean	Std. Error	95% Confidence Interval	
Food	Nature	1.413	0.034	1.345	1.48
	Processed	1.404	0.036	1.333	1.475
No Food	Nature	1.447	0.039	1.37	1.524
	Processed	1.429	0.033	1.364	1.494



Manipulability*Process State

Manipulability	Processed	Mean	Std. Error	95% Confidence Interval	
Whole hand	Nature	1.449	0.035	1.378	1.52
	Processed	1.395	0.032	1.331	1.459
Precision	Nature	1.411	0.037	1.337	1.485
	Processed	1.438	0.036	1.366	1.511



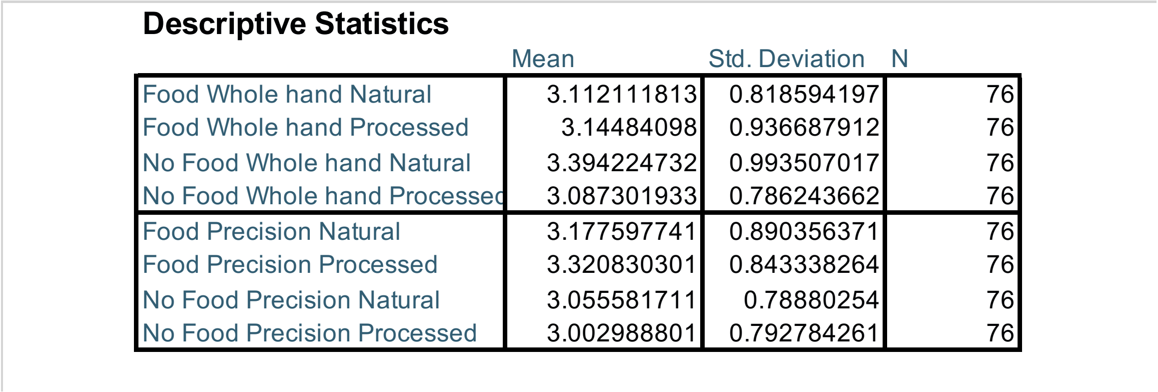
Manipulability*Food*Process State

Food	Manipulability	Processed	Mean	Std. Error	95% Confidence Interval	
Food	Whole hand	Nature	1.398	0.031	1.336	1.461
		Processed	1.322	0.032	1.257	1.387
No Food		Nature	1.5	0.041	1.418	1.581
		Processed	1.468	0.033	1.402	1.535
Food	Precision	Nature	1.427	0.038	1.351	1.503
		Processed	1.487	0.04	1.407	1.566
No Food		Nature	1.394	0.038	1.32	1.469
		Processed	1.39	0.034	1.323	1.457

3.6 Analysis six: All-together b-CFS

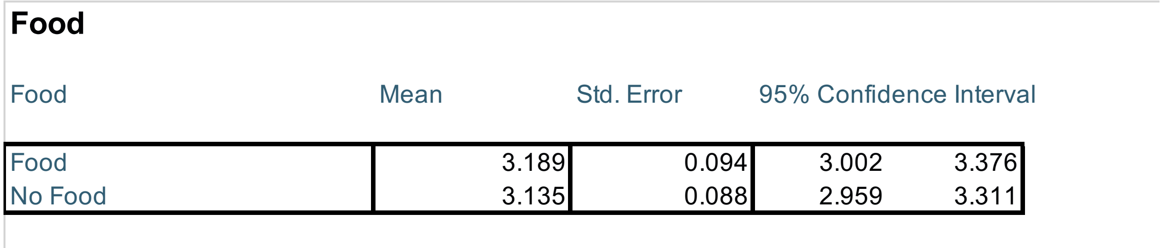
There was no main effect of Food (see all means and standard deviations in table 4) [F(1,75) = 3.134, p=.08), no effect of Manipulability [F(1,75) = 2.625, p=.109], nor a main effect of process state [F(1,75) = 2.402, p= .125]. A significant interaction between Food*Manipulability [F(1,75) = 30.28, p=.000] was found. For objects affording a whole hand grasp, RTs were faster for food versus no-food items and the opposite was true for objects that afford a precision grasp. Another significant interaction was found, this time for Food*Process State [F(1,75) = 21.267, p=.000] where food nature was faster than Food Processed and the relationship was inverse for no-food items. Also a significant interaction between Manipulability*Process state = [F(1, 75) = 7.881, p=.006]. RTs for stimuli affording a whole hand grasp that are processed were faster than nature objects. The opposite was found for objects affording a precision grasp. The 3-way interaction was not significant [F(1,75) = 1.092, p=.299].

TABLE 4. b-CFS All together



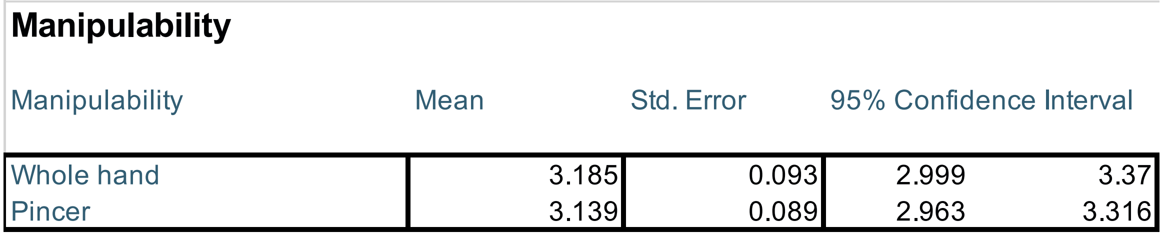
Descriptive Statistics

	Mean	Std. Deviation	N
Food Whole hand Natural	3.112111813	0.818594197	76
Food Whole hand Processed	3.14484098	0.936687912	76
No Food Whole hand Natural	3.394224732	0.993507017	76
No Food Whole hand Processed	3.087301933	0.786243662	76
Food Precision Natural	3.177597741	0.890356371	76
Food Precision Processed	3.320830301	0.843338264	76
No Food Precision Natural	3.055581711	0.78880254	76
No Food Precision Processed	3.002988801	0.792784261	76



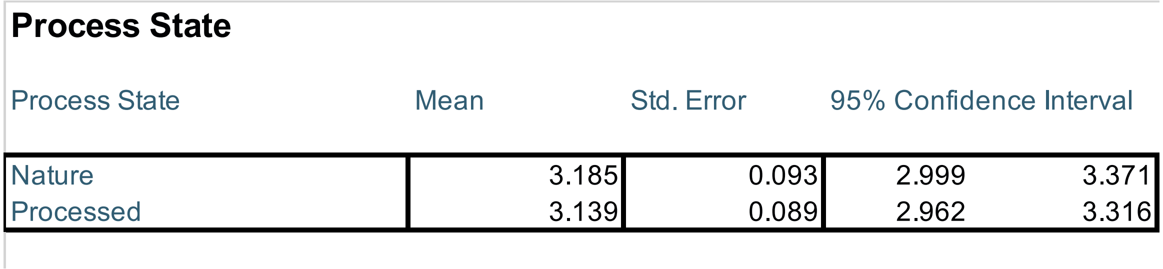
Food

Food	Mean	Std. Error	95% Confidence Interval	
Food	3.189	0.094	3.002	3.376
No Food	3.135	0.088	2.959	3.311



Manipulability

Manipulability	Mean	Std. Error	95% Confidence Interval	
Whole hand	3.185	0.093	2.999	3.37
Pincer	3.139	0.089	2.963	3.316



Process State

Process State	Mean	Std. Error	95% Confidence Interval	
Nature	3.185	0.093	2.999	3.371
Processed	3.139	0.089	2.962	3.316

Food*Manipulability

Food	Manipulability	Mean	Std. Error	95% Confidence Interval	
Food	Whole hand	3.128	0.096	2.937	3.32
No Food		3.241	0.095	3.051	3.43
Food	Precision	3.249	0.096	3.059	3.44
No Food		3.029	0.086	2.858	3.201

Food*Process State

Food	Process State	Mean	Std. Error	95% Confidence Interval	
Food	Nature	3.145	0.093	2.959	3.331
	Processed	3.233	0.098	3.037	3.429
No Food	Nature	3.225	0.097	3.032	3.418
	Processed	3.045	0.085	2.877	3.213

Manipulability*Process State

Manipulability	Processed	Mean	Std. Error	95% Confidence Interval	
Whole hand	Nature	3.253	0.099	3.056	3.451
	Processed State	3.116	0.093	2.931	3.302
Precision	Nature	3.117	0.092	2.934	3.3
	Processed State	3.162	0.09	2.983	3.341

Manipulability*Food*Process State

Food	Manipulability	Processed	Mean	Std. Error	95% Confidence Interval	
Food	Whole hand	Nature	3.112	0.094	2.925	3.299
		Processed	3.145	0.107	2.931	3.359
No Food		Nature	3.394	0.114	3.167	3.621
		Processed	3.087	0.09	2.908	3.267
Food	Precision	Nature	3.178	0.102	2.974	3.381
		Processed	3.321	0.097	3.128	3.514
No Food		Nature	3.056	0.09	2.875	3.236
		Processed	3.003	0.091	2.822	3.184

4. Discussion

Obesity is a worldwide epidemic that has been growing for the last 30 years, despite the public health efforts to decrease the numbers of people affected. According to Friedman (2004), in North America 30% of people are overweight (BMI, Body Mass Index, height per weight in kg/m>25) and 40% are obese (BMI >30). The number of morbidly obese individuals continues to increase at an alarmingly rate. Obesity is associated with other diseases that shorten quality life and life expectancy. The general belief regarding obesity is that there is a lack of self-discipline and that losing weight is about eating less and exercising more. Consequently, the main efforts in research have been directed to understanding the homeostatic aspects of the disease. However, diet and exercise, are processes controlled with great precision by the intercommunication of the central nervous system, the digestive system, and fat tissue (Bouret et al., 2004). In the past few decades we have seen little success in controlling patient's food intake and energy expenditure (Leibel et al., 1995). There have been multitude of treatments including diets that demonized one macronutrient or another (e.g. fat, sugar), pharmaceuticals that inhibit hunger, eliminate fat, or even augment mitochondrial cell energy consumption, and even surgery (bariatric), all with little to no success. Even when a treatment seems to initially work, most people will regain the weight and even gain more after a few weeks or months (Leibel et al., 2015). With this grim outlook, research now is looking for other variables that could be responsible for the obesity epidemic and for ways to fix it.

Cognitive processes such as inhibition and planning play a very significant role in successful dieting and losing weight according to some researchers (Papies et al., 2008). Higher brain cortical areas are involved in constraining urges to eat and controlling general behavior towards food (Kaye et al., 2013). Maintaining what is considered a healthy body weight is a big cognitive effort, which most people fail to accomplish. Nowadays, being lean is even considered a socioeconomical status advantage (Keane et al., 2012) probably because leanness requires a considerable amount of time and effort to fight the environmental pressures (e.g. endless availability of food, marketing, highly processed palatable foods) that lead to the gain of weight.

One of the gaps in understanding how humans maintain and/or gain weight, is the paucity of knowledge regarding how sensory and cognitive functions influence food choices. We do not know how sensory and cognitive information are integrated to drive our decision of what and how often to eat and to what degree this information is processed consciously. In the spectrum of eating disorders, anorexic patients can restrain themselves to the point of starvation, while obese remained eating until illness. There is not only the question of how humans respond to sensory food cues, but also of how much volition is involved in these responses.

The term "obesogenic environment" is used to describe our industrial modern society where the mixed of different factors have conclude in the rising of obesity: availability of a high processed food products, a less availability of nutriments, socioeconomical status and less physical activity (Townshend & Lake, 2017). It is also where food cues especially visual ones, are everywhere around us. It has been argue that these food cues encourage our desire to eat (Boswell & Kober, 2016). The cephalic phase of eating, where there is no food yet in our mouth, but is visible (or imagined) is thought to be the start of digestion. This stage is important because contributes greatly (~50%) of the total postprandial acid production; this is mediated entirely by the vagus nerve, which is called the neural link between the brain's higher functions and gastric secretion (Feher, 2012). In other words, the sight, smell, or thought of food can start the digestive process.

Eating involves many senses and is a multifaceted behavior involving appetite, reward, motivation, but also attention. Visual attentive processes involve both exogenous and endogenous factors. Exogenous factors are those that are independent of the state of organism (e.g. hunger levels). Endogenous factors can be volitional and depend on the organism's state, which means every individual will direct their attention toward objects relevant for them. For example, hunger levels are affected by visual cues that invoke pleasure of certain foods (a chocolate cake is always attractive, but it would be much more attractive if the person is hungry; see Hickey et al., 2010). In the case of exogenous factors, specific for food, calorie content is a variable from the object that can drive attention, especially if those calories come from fat. Toepel et al. (2009) find that the brain (using event-related potentials, ERPs) has the ability to track energy content as soon as .165 seconds. Also, Sawada et al. (2017) compared Japanese food and fast-American food in a visual search task, finding that the preference is only for the high-fat fast foods even amongst a Japanese participant's sample. For endogenous factors, body mass index (BMI) is positively correlated with food intake regulation. This also has been linked to the reward system, meaning that higher BMI individuals find food so rewarding that are programmed to find it first. However, Nummenma et al. (2011), described an inverse relationship between BMI and food detection, meaning lean individuals are the ones who find food faster (perhaps because they are hungry). So, visual attention can be driven by bottom-up mechanisms, but also top-down, where the higher cognitive processes come in.

Previous studies have found an effect of food in visual attentive processes, but there is still no consensus as to how voluntary these effects are. In a working memory and attention study by Kumar et al (2016), the authors found that when participants have food as a target, reaction times (RTs) were shorter for this type of stimuli. Interestingly they also found that when food is used as a distractor, errors in finding other stimuli (e.g. a car) increased. These results suggest that food not only captures attention, but that it is also difficult to ignore.

In the present thesis I test the hypothesis that food is detected faster. I also investigate if other intrinsic characteristics of food items are important to their detection. Two of these characteristics are the process state of the food (natural vs. processed), as well as their manipulability (if the object can be grasped with a precision or a whole hand grasp). Importantly, because previous research has demonstrated an advantage for detecting food, I wanted to test if this advantage can occur before awareness. In order to test a visual food advantage without awareness, I used a b-CFS paradigm.

b-CFS is a version of a binocular rivalry technique, where a flashing colorful Mondrian or abstract picture is presented to one eye while to the other eye an image of an object is presented. The idea is that the disorganized pattern of colors of the Mondrian 'distracts' the primary visual cortex, so the target image gets suppressed for a few seconds. The suppression occurs even though the image is projected to the retina, thus we are not aware of the image until a range of time happens (up to eight seconds). Interestingly, this technique does not suppress all categories of images equally, it has been argued that there is a preference for some objects (usually related to survival) and awareness of these occur faster than for other objects (Gayet et al., 2016). The b-CFS technique introduced by

Tsuchiya and Koch (2005) shows that access for awareness is preferred for certain objects even inside categories. Some objects that breaks the suppression first are: tools such as knives, faces that show anger instead of other emotions, and also an upright face pattern instead of an inverted one.

I tested the hypothesis that food could have access to awareness faster that other stimuli and that this would be apparent, by breaking the suppression first in a b-CFS versus No b-CFS paradigms. I reasoned that food objects gain access to consciousness first, implying that information processing of food happens at a very early visual stage and it is automatic.

In the next section, I will review the results collected for the two conditions No b-CFS and b-CFS. Participants were asked to respond to images of objects (FRIDa Database, 2014) presented on a screen. In order to study the effect of food, 40 picture of Food objects and 40 of no-Food objects were chosen from the FRIDa database. The objects were presented for a total of 320 trials where, every object repeated four times at different quadrants of the screen. A secondary aim of my thesis was to investigate if other intrinsic factors of foods would play a role during attention for categorization. To study the effect of manipulability on reaction time, half of the objects in each food category were manipulability by a whole hand grasp and the other half by a precision grasp. The last variable I was interested to investigate were differences depending on the process State of the food. I reasoned that high-caloric food like a hamburger, would elicit faster responses than low caloric foods like broccoli. For this analysis I had 20 objects considered natural and 20 considered processed for both food and no food objects and for both objects affording a whole hand or precision grasp. Every object was part of these three categories, for example a pizza is a food item, manipulable with the whole hand grasp and processed. I measured the reaction time in seconds for every object. RT was measured as the gap of time between the presentation of the object and the pressing of the J or F button. Food, Manipulability, and Processed State were within subject factors for each of the four conditions: No b-CFS (Explicit and Implicit) and b-CFS (explicit and implicit) task.

I will discuss the general results on these two conditions first separately and then when analyzed together.

With the explicit task, I tested if triggering food categorization (participants had to think and decide whether an object was food or not food item) would result in faster RT's. In the case of the No b-CFS, the effect for food was strong and compared to the implicit condition, it took ~.4 seconds more to categorize the objects as food or no food. Importantly, regardless of how long it took to respond to the stimuli presented, in both No b-CFS conditions, food was identified faster. It is also worth to notice that the interaction between Food and Processed state was different between both tasks. In the explicit task, the preference was for natural foods, while in the implicit task it was for processed foods (this tendency, although not significant, was maintained in the b-CFS). The biggest advantage for food was found in the implicit condition. I assume that when the purpose is to simply respond left or right it was easier if the object was food. Adding the categorizing task during the explicit condition delayed this process.

Importantly, the three-way interaction in both explicit and implicit No b-CFS gave the same result: An advantage for food that can be picked up by a whole hand grasp and that was processed (e.g. hamburger). There can be a couple of reasons to explain this result. First, we use whole hand grasps to seize larger objects, so it is likely that using this type of grasp leads to obtaining more calories from the food than using a precision grasp, regardless of the processed state of the food. Remember that when the objects were not food, there was an advantage for precision grasps, suggesting that the faster reaction time had to do with calorie content, which resembles the results of Toepel et al., (2009) and Sawada et al., (2017). These authors find that food has an advantage only if it is high in calorie content. Second, whole hand grasps are ecologically easier than precision grasps because less cognitive effort is required to adjust the hand for a big object than for a small one (Pataki et al., 2012). Finally, developmentally, whole hand grasps appear first, around four months of age, compared to precision grasps, which appear closer to one year of age (Newell et al., 1989). So perhaps one defaults to the most primitive grasping system when challenged with making speeded responses.

The b-CFS explicit and implicit tasks showed different results than the No b-CFS. The first thing to notice is that RTs were faster for the explicit condition. This is puzzling as one would think that simply responding left or right would be easier cognitively (as it was the case in the No b-CFS). It seems that categorizing objects between Food and No Food facilitated breaking suppression. It is possible this type of categorization activates a working memory system that accelerates the process of breaking suppression. So explicitly designating an object as food versus no food may prime working memory systems in a way that when ‘seeing’ a food object subliminally, these systems kick in and make us aware of the object faster.

The interaction between food and process state was significant in the explicit and in the implicit conditions: No food objects that were Processed (e.g. chess piece, lego block) were fastest to break the suppression. In a study reported by Filliter et al. (2005), a subset of non-living objects where faster to detect. Our results are consistent with this finding when using b-CFS. A neuropsychological report of a patient with a progressive degenerative disorder showed very specific impairment in naming “artifacts” while naming living objects was spared (Moss & Tyler, 2000). It is unclear why non-living objects are more salient at least when it comes to measuring reaction time. One could speculate that it has to do with associations between those objects and the motor response that they could elicit. The non-living objects used in this thesis were all manipulable and pressing a key on a keyboard (a non-living object) may have facilitated the response. On the same vein, one could argue that no food processed objects all elicit the potential for action that involve the dorsal stream which is known to process information unconsciously. It is also tempting to speculate that participants recognize non-living things because more and more we live surrounded by these types of objects. Sadly, we have moved away from a natural-rich environment and our interactions with “Nature-made” objects, including non- processed foods, are fewer and fewer.

5. Conclusion

The present thesis makes two important contributions to the field of cognitive neuroscience, specifically regarding visual perception of food cues. First, it replicates other research showing an advantage when categorizing food versus other stimuli. Participants in the No b-CFS responded faster to food regardless of whether their categorization was explicit or implicit. Furthermore, it was found that processed foods that afford a whole hand grasp elicited the fastest responses. Second, this thesis does not confirm the speculation that such advantage for foods may be present at the pre-attentive level. Manipulability and process state clearly play a role in the categorization of objects (foods and others) and should be considered and controlled when studying the behavioral and or neural underpinnings of visual attention of food.

6. Limitations

One important aspect to consider regarding the use of b-CFS and the results obtained from using this technique is that some researchers have taken it with skepticism. The biggest criticisms is whether or not b-CFS really measures consciousness or attention at the pre-attentive level. Yang et al. (2014) for example, recommended having at least one other measure of awareness when using b-CFS. This means, that when b-CFS is used, the task should involve the participant's active effort to keep attending to the task (e.g. determining the location of a target). While the number of errors (e.g. pressing the food designated button for a non-food item) were low in both no b-CFS and b-CFS conditions, it is possible that fatigue played a role, particularly in the b-CFS condition as this session lasted ~40 minutes.

Another consideration is the fact that Mondrians could hinder the perception of some stimuli. Low visual features present in the Mondrians *and* in the target images have been shown to be confounded sometimes (Stein et al 2014). Spatial resolution, color, brightness, were controlled in the stimuli used in this thesis. However, there is the possibility that just by association, some objects were suppressed more because their features (colour) were too similar to the Mondrians. Something else to keep in mind is that we did not control for working memory processes. Gayet et al., (2014) suggested that b-CFS needs active visual working memory and claimed that passive visual recognition keeps RTs unaffected. They asked participants to retain a feature of an object in a "retention phase" (e.g. a face), and then they did the b-CFS task. They found that asking participants to retain information (i.e. activating working memory) before doing the b-CFS task facilitated breaking suppression and they concluded that visual perception can be triggered by working memory at a pre-attentive level. We cannot be certain that by showing participants food objects, this category did not prime participants for further food items.

A study by Nummenma et al. 2011, correlated Body Mass Index (BMI; the measure of mass per meter square) with reaction times to food. Results indicated that RT for food was slower when the Body Mass Index was higher. I did not target high BMI participants to replicate such finding, a big part of my sample were university students, and the average BMI was normal. In the b-CFS, participants with a higher BMI could have different responses than my sample, therefore this need further testing it in the future.

Finally, I did not control for hunger/satiety levels. It is possible that participants that completed the experiment in a hungry state responded differently (e.g. broke suppression faster) than those that had just eaten a meal.

7. Future Directions

It is worth to mention that all of our participants were healthy (as reiterated with the questionnaires) and had a BMI in the normal range. Future studies attempting to further investigate a cognitive profile for obesity, need to include a population of overweight and obese participants.

Another interesting follow up would be to go beyond reaction times and explore the kinematics of actions towards food and non-food objects. This could also be expanded to include objects that afford a whole hand or a precision grasp.

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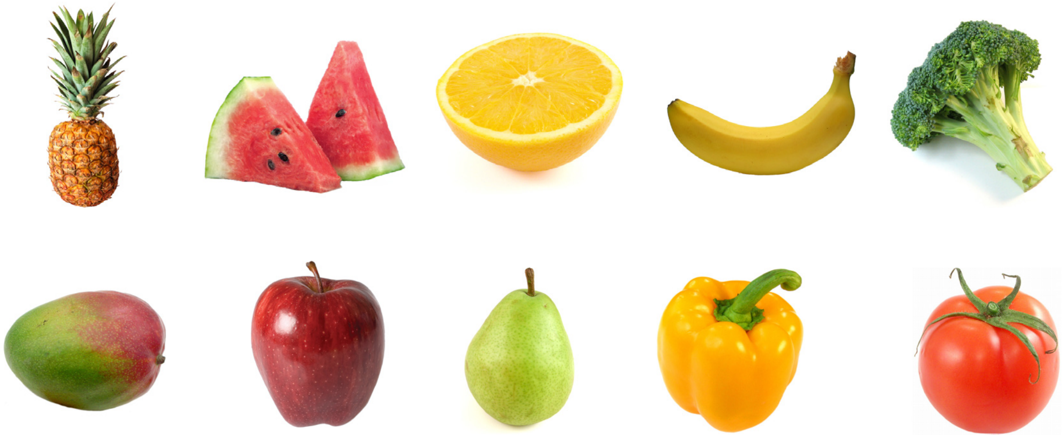
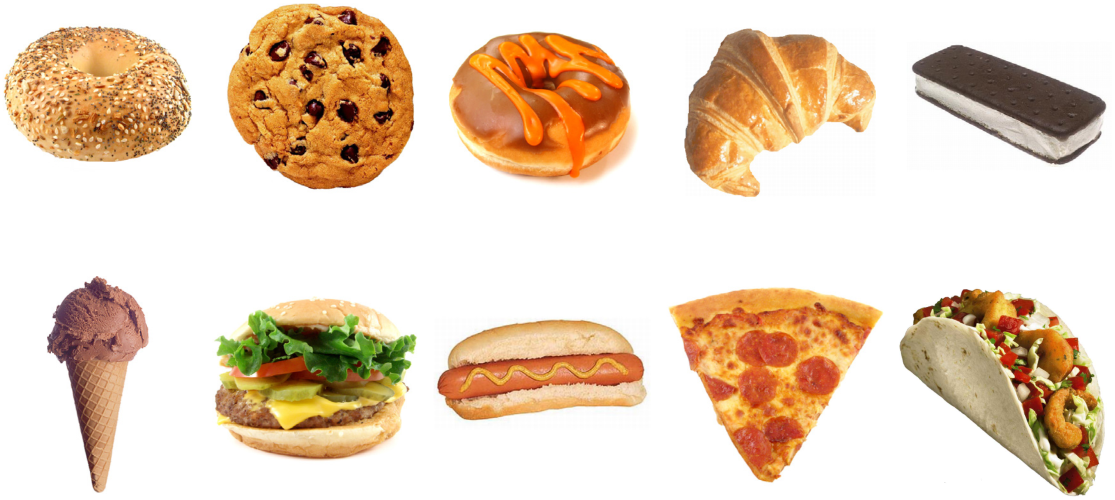
Appendix 1. All objects used in the experiments. Retrieved from The FoodCast research image database (FRIDa) Foroni et al., (2013)

FOOD WHOLE HAND NATURE OBJECTS



FOOD WHOLE HAND PROCESSED



NO FOOD WHOLE HAND NATURE










NO FOOD WHOLE HAND PROCESSED










FOOD PRECISION NATURE OBJECTS










FOOD PRECISION PROCESSED OBJECTS










NO FOOD PRECISION NATURE OBJECTS










NO FOOD PRECISION PROCESSED OBJECTS