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The Neural Correlates of Categorizing Rotated Objects

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by

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1 Abstract

The effects of categorizing rotated objects on the neural correlates of the N400 was investigated using a word-picture match task. The level of categorization was manipulated by presenting a basic or subordinate word prior to an image displayed at one of four orientations (0°, 60°, 120°, 180°). Participants' task was to identify if the word and the image matched. The N400 component, which shows effects of semantic incongruity, was measured from the time phase 250 to 580 ms. Behavioural results found that reaction times were quicker for matched conditions over mismatched conditions. Basic mismatch conditions also showed faster reaction times versus subordinate mismatch as expected, however basic level categorization matched showed slower reaction times than subordinate level which was not expected. As predicted, reaction times for orientation showed a significant quadratic trend with 0° displaying the quickest reaction time. This increased for 60° and 120°, whereas reaction time then decreased for 180°. EEG results showed basic categorization had a lower amplitude on the N400 versus subordinate categorizations, as did mismatch conditions due to the higher level of semantic incongruity which has been identified in previous studies. The effect of orientation on the N400 differed depending on the level of categorization with only subordinate showing significantly more negative amplitudes. Possible reasoning of this is due to basic categorization not requiring transformation. The N400 correlates with semantic processing as when basic categorization mismatches was involved, less semantic information and higher incongruity correlated with more negative amplitudes of the N400.

2 The Neural Correlates of Categorizing Rotated Objects

2.1 Background Theory

Rosch, Mervis, Gray, Johnson, and Boyesbraem (1976) proposed that objects can be identified at varying levels. It was suggested that objects are recognised fastest at an intermediate level of specificity, called the basic level of processing, for example when a Labrador is identified as a dog. The basic level is the most abstract level of categorization in which integrated perceptual representations of a category can be formed. It is also the most inclusive category in terms of object identity, semantic, motor information and shape. Basic level categorizations allow an optimal combination of distinctiveness between classes of objects and information within a class. This allows for example a cat and a dog to be identified as distinct and allows for additional information not available in superordinate categorization. This superordinate categorization is a more general level of categorization, for example a Labrador being identified as an animal. The more specific level is responded to the slowest, this is the subordinate level for example a Labrador is identified as a Labrador. The subordinate level allows the acquisition of more detailed information about the object, but the additional information about the object comes at a cost to distinctiveness. Due to a Labrador and Golden Retriever being less distinct from one another than at a basic level of a dog and a cat, or an even greater distinction at a superordinate level of an animal and a bird.

One explanation as to why naming an object at a basic level is faster than at a subordinate or superordinate level is due to the naming of the objects. At a basic level the names for the objects on average contain fewer syllables in comparison to that of the names at a subordinate or superordinate level. People are also more frequently exposed to basic names. Research has shown that having fewer syllables in a name and word frequency has been correlated to naming reaction times (Biederman, Subramaniam, Bar, Kalocsai, & Fiser, 1999). Basic names have also been shown to be learnt first by children (Anglin, 1976; Horton & Markman, 1980; Mervis & Crisafi, 1982). The advantage basic level naming has could also be due to the perceptual information required to classify an object at basic level. Basic level information is more discriminable and salient in comparison to the information required for subordinate naming (Rosch et al., 1976). A further explanation is that acquiring the representation of an object and its name might be more readily available at a basic level, possibly in result of the greater frequency of basic level distinctions made in comparison to subordinate and superordinate level distinctions (Biederman et al., 1999).

Jolicoeur, Gluck, and Kosslyn (1984) also propose a theory of how an image and a word are matched at varying categorization levels. Firstly visual stimuli are classified dependent on the corresponding information stored on the stimuli, this is done by a perceptual processing mechanism. Activation then spreads upwards from the entry point where further information is gained, both more specific information (subordinate classification) and more general information (superordinate classification). For typical category members basic level effects are observed due to basic level nodes serving as an entry point. For example, the visual stimuli of an owl would first activate the bird node as it is a typical stimuli. Atypical category members fail to show basic level entry as their entry level is more specific, for example a penguin would first activate the penguin node rather than the bird node, this would take longer to activate. Differentiation theory is an alternative explanation as proposed by Murphy and colleagues (Murphy, 1991; Murphy & Brownell, 1985). This theory discusses that basic level advantages arise due to them being both distinct and informative. The speed in which the information is retrieved across the differing categorization levels may be influenced by the differing structural properties. For instance, the superordinate level may be slower to activate as it provides a poor match of information to other stimuli. The subordinate level may be slower due to its competition with the high volume of matches to other alternatives that need to be resolved. The differentiation theory is advantageous as it explains why for some concepts, for example chicken, people are faster to identify them at a subordinate or superordinate level rather than at a basic level (Rips, Shoben, & Smith, 1973).

2.2 Time course of Categorization

The varying levels are shown to occur in a specific manner. Basic being the fastest occurring of the three as this happens first, this enables semantic processing to occur to progress onto subordinate and superordinate processing (Jolicoeur et al., 1984; Rosch et al., 1976). Basic level identity is gained from either the global shape of an object (Biederman, 1987; Collin & McMullen, 2005) or the distinctive basic features (Collin & McMullen, 2005; McMullen & Jolicoeur, 1990). This allows the identification at a basic level however it is also indistinguishable from subordinate categorization. To enable a precise identification at the subordinate level further perceptual processing occurs and finer visual details are gathered. The basic level also allows access to the superordinate processing, due to people having the ability to match the incoming image with a set of disjointed visual features that can make up the superordinate categorization. This level of identification takes longer than the basic as the features are disjointed therefore more time is required to match the perceptual input with a superordinate category from the semantic memory (Jolicoeur et al., 1984). Superordinate processing occurs once searching of the semantic memory is complete after basic processing (Jolicoeur et al., 1984).

Despite this, not all research has found that basic always occurs first. Research which required participants to identify if an animal or vehicle was present within an image, found that participants reaction times showed that superordinate processing took place 150 ms post stimulus based on changes in brain activity shown by event related potentials (ERP). The short reaction times here show some evidence that visual processing requires a basic level identification before superordinate as suggested by Rosch et al., (1976). It is noted that it is highly unlikely for any visual processing task that would require a greater level of analysis of the image could be performed with reaction times that are faster than those presented in this study for superordinate level of identification (VanRullen & Thorpe, 2001a, 2001b).

In order to investigate a more specific time course of the processing ERP is used as the technique allows for more direct links between recorded signals and stimulus events, to enable the focus on the change of the electrophysiological signal that occurs immediately after a stimulus event (Key, Dove, & Maguire, 2005). These changes over the time of an experiment provide information at milliseconds intervals about sensory, perceptual, cognitive and motor processing at different brain regions (Kutas & Federmeier, 2000). Information about the differing processing occurring can be measured at millisecond intervals due to the high temporal resolution of the technique, this is vital as it allows the recording of momentary changes in patterns of brain activation that may have been otherwise unnoticed (Key et al., 2005). This is important in investigating the process of identifying rotated objects at varying orientations as the use of semantic memory can be tracked during language comprehension tasks in real time (Kutas & Federmeier, 2000).

Electrophysiological studies such as the one carried out by Tanaka, Luu, Weisbrod, and Kiefer (1999) compared basic, subordinate and superordinate processing. Participants had to make a true or false decision in regards to the matching of the image and name displayed. Tanaka, Luu, Weisbrod, and Kiefer (1999) analysed their electroencephalogram (EEG) results by averaging within a time window to analyse the difference in the amplitude of the ERP components and investigate if they differed in the varying conditions. Their results showed that at posterior sites there was an early event-related potentials component

(N1) for the subordinate category in comparison to the basic category. In addition to this, superordinate processing produced larger negativity at the frontal areas versus basic processing. A negative deflection between 306 and 356 milliseconds (ms) in frontal sites differentiating basic and subordinate processes was also found. The enhanced N1 was argued to show difference in the visual processing for basic and subordinate categorization and in addition to that, the frontal electro-negativity demonstrated semantic processing differences in superordinate and basic categorization.

In order to get a distinct time period for the varying levels of identificiation several ERP studies have been carried out using different tasks and methods. Johnson and Olshausen (2003) research required participants to show if the stimuli contained a target or not. The stimuli used was images of animals and nature scenes. ERP analysis showed that the earliest components were 150 to 300 ms correlating to reaction time. In contrast to this previous research has showed that recognition components arise from 150 ms (Fabre-Thorpe, Delorme, Marlot, & Thorpe, 2001; Thorpe, Fize, & Marlot, 1996). The early onset of 130 to 150 ms corresponds to the different visual processing of the varying image types used in previous studies. Johnson and Olshausen (2003) analysis also showed that superordinate categorization occurred around 207 ms. Johnson and Olshausen (2003) however measured the divergence of averaged ERP signals from two different conditions therefore their timings cannot be compared to those found by Tanaka, Luu, Weisbrod, and Kiefer (1999).

A magnetic source imaging study carried out by Low et al. (2003) using magnetoencephalographic (MEG) recordings, further investigated the time periods of the levels of identification. Participants had to indicate whether a stimulus from four superordinate categories which related to four basic categories, was man-made or natural. Low et al. (2003) results found within the time frame of 170 to 210 ms the neuromagnetic activity was more similar for basic level category belonging to the same superordinate category than the basic level category belonging to a different superordinate category. This analysis shows that images can be evaluated for properties relevant for superordinate processing at the early stages of visual categorization.

2.3 Orientation and Categorization

Hummel and Biederman (1992) proposed a theory of the neural network of object recognition which includes the perceptual and post-perceptual classification. The object layer theory refers to individual units that represent a structural description of an object, for example the parts of an object and how they relate. The units that represent the objects name and semantic information are associated with the object. The connection between the object units, the name and semantic information is not related to the ease in which the object unit can be activated by a particular image. Therefore, if a nonsense object is presented but it is made up of clear simple parts, it can still activate an object node. This activation of an object node is what Biederman (1987) named primal access. Primal access is the first activation of perceptual input from an unforeseen object to a representation in memory.

Human object representation of previously encountered objects can be explained using two different representations, viewpoint dependent and viewpoint independent. There are two approaches which are consistent with the two representations, these are the multiple views and structural descriptions approaches (Tarr & Kriegman, 2001). The structural description approach is based upon the theory of the configuration of three-dimensional parts (Biederman, 1987; Hummel & Biederman, 1992). The stages of processing in the structural description approach as outlined by Biederman (1987) are as follows. Firstly, the extraction of surface characteristics such as colour, texture and luminance is carried out to provide a line drawing description of the object. The line drawing allows the nonaccidental properties of the image edges to be detected and simultaneously to this, parsing is performed. Parsing is performed at the concave regions of the object. This simultaneous identification of the nonaccidental properties of the parsed areas gathers information on the critical constraints on the identity of the components. The determination of an objects components can be delayed and this will have a direct effect on the time taken to identify the object. The components are then matched to object representations and the matching of the components is assumed to occur in parallel with an unlimited capacity. Once the match occurs to an object representation, then the image is identified.

The multiple-views approach on the other hand is based upon features and images that are viewpoint specific (Bulthoff & Edelman, 1992; Poggio & Edelman, 1990; Tarr, 1995). The multiple-views approach does share some similarities with the structural description approach. One similarity being that both discuss that multiple representations are in result of self-occlusions of an object. New configurations of distinct representations when features of the object become visible or are hidden, these new distinct representation can be referred to as a view or an aspect. Both approaches agree that a new distinct representations are developed when there are changes in particular features due to the viewpoint of the object (Biederman & Gerhardstein, 1995). The multiple-view approach discusses that views are specific to familiar viewpoint in addition to this response times will vary depending on the familiarity of a viewpoint (Tarr, 1995; Tarr & Pinker, 1989).

These two different approaches to object recognition both rely on the prediction that representation occurs at a visio-spatial format. The organization of representations is hierarchal not arbitrary, as it includes both exemplar-specific and categorization information of the object. An essential component to the process of recognition is the ability to identify the object and identify it at its varying levels of specificity despite its viewpoint, this is achieved through the matching of the objects' shape and stored representations (Tarr & Kriegman, 2001).

The ability to recognise and identify an object despite its viewpoint requires mental rotation. Mental rotation is the mental transformation of a stimuli displayed at an orientation that is not its normal upright position to its normal upright position. The stimuli is mentally rotated into a standard view, this is in order to determine if two stimuli match due to one being rotated (Searle & Hamm, 2012; Shepard & Metzler, 1971). The mental rotation process requires the knowledge of the shortest angular difference and in order to gain this information, the stimulus' normal upright position is a requirement in addition to the identification of the stimulus. The identification of the stimulus is suggested to happen prior to mental rotation, this allows for the global shape to be processed (Searle & Hamm, 2017). Behavioural analysis has shown that when mentally rotating images the reaction times linearly increase for orientations 0˚ to 120˚, this is consistent with the idea that mental rotation occurs through the shortest angular difference (Jolicoeur, 1985).

Hamm and McMullen's (1998) carried out a study in which participants viewed a word, (basic, superordinate or suboridnate categorization) a rotated image and responded by indicating if they were a match. Analysis showed that at orientations 0˚ to 120˚ orientation effects were present depending on the level of categorization. A significant effect of object orientation was associated with the subordinate names, however insignificant effects were found for the basic and superordinate levels of categorization. This finding suggests that for basic and superordinate categorizations the representations are orientation-invariant, therefore identification occurs without the requirement for any transformation (Biederman, 1987; Corballis, 1988; Jolicoeur et al., 1984).

It is to be noted that within Hamm and McMullen's (1998) research the data for 180˚ was not used within the analysis. This was due to the lack of evidence as to how stimuli are mentally rotated at 180˚. There are several explanations as to how participants rotate 180˚ stimuli, some rotate within the picture plane whereas some flip the image (Murray, 1997). If the rotation is carried out within the picture plane it may be named faster due to not requiring the additional time to work out the shortest angular difference. Joliceour (as cited in Murray, 1997) discussed the first theory of rotating within the picture plane. This theory explains how 180° rotations allow for rotation using orientation-free features and parts to allow the identification of the object. The spatial relations are not encoded for the parts and features. This process of extracting features that are not effected by orientation results in the faster reaction times for 180° in comparsion to 60° and 120°. The second theory of mentally flipping the object rotated to 180° refers to the process which occurs through a reflection transformation in the depth plane around the horizontal axis (Koriat, Norman, & Kimchi, 1991). Reflective transformations only occur at 180° due to the alignment of top and bottom axis are unique to orientations 0° and 180°. This mentally flipping process has also shown to result in faster response times and has been supported in various studies (Bressan & Vicario, 1984; Parsons, 1987). The type of stimuli is also a factor to consider when investigating the effects of orientation on object recognition as it has been found that for familiar objects the time taken to respond linearly increases from 0° to 120° but then decreases at 180° (Hamm & McMullen, 1998) however for abstract block figures response times are slowest at 180° versus 0°, 60° and 120° (Searle & Hamm, 2017).

Further specific investigation is required in order to gain more information on the subtle processing that occurs during the categorization of rotated objects, and for this additional analysis techniques are required. Neuroimaging studies have identified a number of regions associated with mental rotation, with the dorso-lateral fronto-parietal network being the main area actively involved with mental rotation (Milivojevic, Hamm, & Corballis, 2011). Few ERP studies have been carried out to investigate the effects of mental rotation however those that have, suggested that mental rotation is represented by increases in parietal negativity in both hemispheres which begins around 400 ms post stimulus until 610 ms (Milivojevic, Hamm, & Corballis, 2009).

The time phase of 400 ms post stimulus is also associated with the ERP component the N400. The N400 is associated with auditory and visual comprehension tasks and presents itself as negativity peaking around 400 ms post stimulus (Key et al., 2005; Kutas & Federmeier, 2011). Kutas and Hillyard (1980) first identified the N400 when investigating the effect of incongruous words at the end of a sentence that did not match with the semantics of the rest of the sentence. The N400 is suggested to be the brains response to words but becomes more negative in relation to the level of incongruity (Key et al., 2005). The N400 has been shown to vary with the processing of semantic information. The neural processes of the N400 represent the language content held in the working memory and the context-independent relationships between stimuli held within the long term semantic memory. The organisation of the long term semantic memory affects language processing as well as the content. The effect of the semantic memory organisation is larger when the contextual constraints are larger, as the N400 amplitude showed greater negativity when there was higher level of semantic incongruity. A higher level of incongruity relates to when the word at the end of the sentence was highly unexpected and was far from being semantically congruent to the rest of the sentence (Kutas & Federmeier, 2000).

The meaning of representation within the brain is related to the N400 as the processing of any meaningful stimuli such as words and images elicit a negative amplitude between 250 and 500 ms post stimulus. As is the case for words, this suggests that all types of meaningful stimuli are a function of semantic, associative and repetition priming (Kutas & Federmeier, 2000). Semantic processing for words can be examined by the semantic priming effect. The semantic priming effect is when the response time to a stimuli is effected by meaningfully related preceding stimuli. For example, response times are faster when deciding if a target word (e.g. lemon) is a real word or a pseudo word when preceded by a meaningful word (e.g. bitter) in comparison to a non-related word (e.g. animal). This has not only been shown for words preceding words but also for pictures and preceding words (Ganis, Kutas, & Sereno, 1996). Semantic priming is explained by two cognitive mechanisms, the first being that the activation of corresponding representation of the semantic network is as a result of the presentation of the target stimuli. The activation then spreads to related semantic nodes which increases the activation levels. The second theory is that semantic priming is due to attentional processes. The first cognitive mechanism is more influential within research, due to it referring to a relationship of semantic similarity between stimuli after access to the lexical information. This is supported by results that show when semantic mismatches are detected response times to lexical decision tasks slow down due to the process of facilitating an answer when the stimuli is not matched (Kiefer, 2002; Kutas & Federmeier, 2011).

Reduction in semantic expectation can also be linked to processing objects at a basic level. Basic level names provide less semantic information than subordinate names therefore reducing the semantic expectation for the proceeding object, which in turn is known to reduce the amplitude of the N400 (Hamm, Johnson, & Kirk, 2002; Kutas & Hillyard, 1984). Hamm et al. (2002) carried out research investigating the effects of basic and subordinate level categorization on the N400. Participants carried out a word and picture task, with basic and subordinate mismatch and match conditions. The electrophysiological analysis showed that all mismatch conditions except basic showed a more negative amplitude at the time window 250 to 650 ms (N400) in comparison to match conditions, on midline electrodes Fz to Pz. The difference between the match and mismatch conditions for the basic category were identified in a more centralised location on electrode Cz and within a shorter time period of 350 to 650 ms. The analysis showed that for both subordinate and basic conditions the N400 was elicited with the amplitude being more negative for mismatch conditions over matched conditions.

There are very few ERP studies that have investigated the effects of basic and subordinate processing on the N400 in addition to the effect of object orientation. The effect of orientation on object categorization has been widely researched for behavioural data (Hamm & McMullen, 1998; Jolicoeur, 1985; Searle & Hamm, 2012, 2017). In spite of this, to date there has been no investigation into the effects of identifying objects at differing category levels when the objects are also being manipulated by orientation and therefore the effects on the N400 are not known.

The present study has been designed in order to fill the gap within the literature as it investigated the amplitude differences of the N400 when objects being viewed at different orientations were being identified at two different categorization levels. A word-picture match task design was used as this design reliably shows match and mismatch effects on the N400. The word being displayed first also allows the manipulation of which level the stimuli will be categorized. As the participants will be assessing if an object belongs to a category or not it allows the chance-level performance to be equalized to 50%. Due to the design of the task with the word being presented first therefore the semantic category is assessed from the word, it may not show the same categorization processes as historically shown in other categorization tasks. The participants are able to make a representation of what they anticipate to be coming up however in the case of the stimuli, they would not be able to anticipate at which orientation the stimuli was going to be displayed at (Collin & McMullen, 2005).

The time period of the N400 chosen was 250 to 580 ms and this was selected due to being within the time period used in previously successful studies (Angwin, Phua, & Copland, 2014; Hamm et al., 2002; Hurley, Paller, Rogalski, & Mesulam, 2012; Khateb, Pegna, Landis, Mouthon, & Annoni, 2010; Kutas & Federmeier, 2000). The design also allowed for a large number of trials to be carried out in order to investigate the effects of basic and subordinate categorization as well as orientation manipulation of varying angles (0°, 60°, 120°, 180°) on the N400 component.

Based upon the results from previous behavioural and ERP studies it is expected that our results will show that the basic category will have quicker reaction times for both match and mismatch conditions than the subordinate category. The reaction times are also predicted to be quicker for objects presented at 0° and for the reaction times to linearly increase relative to orientation with 180° showing a slight decrease in reaction time. A further prediction is that the amplitude for the N400 will be lower for basic mismatch conditions in comparison to subordinate mismatch condition due to the higher level of semantic incongruity. The amplitude for the N400 is predicted to also be lower for mismatch conditions versus match conditions due to the violation of expectation. In regards to orientation, the prediction made was that the greater away from 0° the object is presented, the greater the amplitude will be for the N400 and this difference is predicted to be more prevalent for the subordinate category than the basic category.

3 Method

3.1 Participants

Twenty-nine psychology undergraduates from the University of Hull participated, only twenty-seven participants' data were used due to technical issues. Twenty-three of those were females and four were male. The ages ranged from eighteen to twenty-seven, the mean age was 20.19 years (SD= 2.94). All subjects were native English speakers, had corrected or normal vision and had a BMI lower than 25. Participants took part in return of course credits. All participants gave their written, informed consent and filled in a health questionnaire prior to taking part. Ethical approval was granted by the Ethics Committee at the University of Hull, Psychology department, School of Life Sciences.

3.2 Stimuli

The stimuli used were selected from 1,530 images, which had been gathered from various internet sources. An example of our image stimuli is shown in Figure 1. All images were edited using Adobe Photoshop CS2 in order to adjust the contrast using the automatic contrast setting. This adjusted the colour images into grayscale and was applied in order to make the images look clearer and neater on the white background within the experiment. If any of the images had grey shading around the image this was also removed using Photoshop CS2. The varying orientations (0˚, 60˚, 120˚ and 180˚) that the images were displayed at was created using MATLAB 7.5.0 (R2007b). The words displayed prior to the image were displayed with only the first letter being uppercase for example Poodle. The size of the stimuli on the screen was 256 by 256 pixels, in the centre of the screen.

The primary image stimuli dataset included 17 images for each subordinate category for example, Golden Retriever. There were 5 subordinate categories, 9 basic categories, therefore overall there was 45 image categories, shown in Table 1. Due to the stimuli being collected by Professor Charles Collins in Canada, the colloquial terms used for the labels required verification to ensure that the terms were understandable to our native English speaking participants. This process was undergone by clarifying the understanding of the terms to a small group of native English speakers. As a consequence of this, some of the labels were changed for example jean jacket was changed to denim jacket and in addition to this, the image set labelled flounder was removed due to the lack of recognition and inability to match the subordinate name to the image. Once all appropriate changes were made to the stimuli dataset the final image stimuli dataset consisted of 595 images overall, made up from 17 images for each of the 35 subordinate categories within the 9 basic categories, as can be seen in Table 1. One image was taken from the dataset of 17 for each subordinate and basic category and was used as the stimuli in the practice trials allowing the other 16 images to be used in the main task. Table 1 illustrates the categories used and it displays the categorical relationships between the words.

Table 1. Names of the image stimuli and the categorical relationships.

Category Level	
Basic	**Subordinate**
Bird	Chicken, Duck, Owl, Parrot
Fish	Clown Fish, Goldfish, Shark, Swordfish
Dog	Bulldog, German Shepard, Golden Retriever, Poodle
Hat	Baseball Cap, Cowboy Hat, Graduation Cap, Top Hat,
Jacket	Denim Jacket, Leather Jacket, Raincoat, Suit Jacket
Shoe	Stiletto Shoe, Trainer, Sandal, Slipper
Boat	Battleship, Canoe, Sailboat
Car	Formula One Car, Limousine, Police Car, Sports Car
Truck	Fire truck, Bin Lorry, Pickup Truck, Tow Truck

3.3 Procedure

The experiment consisted of 1152 trials which made up 6 blocks containing 192 trials. The order in which the stimuli images and words appeared on the screen was randomised, in addition to the orientation that the images were displayed. This was done by the software MATLAB 7.5.0 (R2007b) which the experiment was ran on. All participants completed all 16 conditions which included the four trial types of match basic, mismatch basic, match subordinate and mismatch subordinate at the four orientations of 0°, 60°, 120°, 180° with 60° and 120° rotated clockwise and anti-clockwise, please see Figure 1 . Each block was made up of a random amount of trials for each of the 16 conditions. The practice block consisted of 10 trials. The order of the words and images as well as the orientations was randomised.

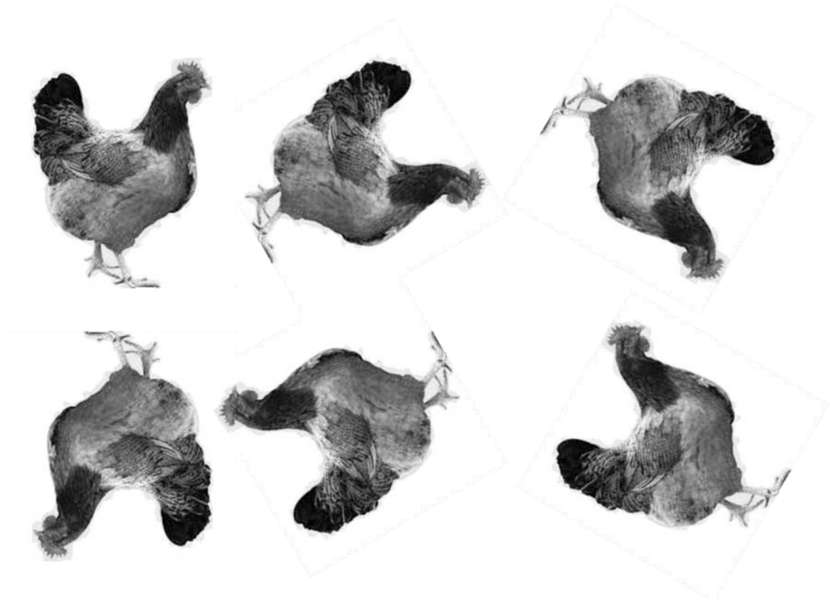

Figure 1. An example of one of the chicken image stimuli as it was displayed at 0°, 60°, 120° and 180° clockwise and anti-clockwise.

Participants took part in the experiment in the room next door to the control room, in which the experimenter could monitor the participant throughout using a video camera live feed. This was to ensure the safety of the participant and smooth running of the experiment. The participants were also made aware that they were able to stop the experiment at any point or were able to speak to the experimenter by waving to the camera and the experimenter would go in and assess the participants concerns. In the control room the experimenter had two computers in order to monitor the participants' EEG trace and the experiment progress. In the experiment room, the participant was sat 90 cm away from the 22 inch 1680 x 1050 pixels Samsung computer screen. The participants were instructed to focus on the centre of the screen and to not move their head to look at the images at the varying angles. Participants were also instructed to avoid any excessive movements and, if possible, to contain any movement to the allocated breaks, they were allowed to blink throughout.

Firstly, the task instructions were verbally explained to the participant, which were expressed to the participants before starting the practice block and main experiment. The instructions page on the screen was then followed with a page to inform the participant which key to press for matched or not matched. The keys were counterbalanced and randomly allocated based on participant number by the software MATLAB 7.5.0 (R2007b). The keys allocated were either ‘s’ for matched and ‘l’ for not matched or ‘s’ for not matched and ‘l’ for matched. Participants were also advised to rest their fingers on these keys throughout in order to allow for the fastest possible response. Participants then underwent the practice trials, once completed the participants had an opportunity to ask any further questions before going on to complete the main task. The participants were also made aware that there was going to specified breaks at the end of every block and also that if required they could have small breaks within the blocks by not responding and therefore engaging the ‘trial timed out’ screen. The participants pressed any key to prompt the next trial after the break and timed out screen, this enabled them to have control over the length of their breaks. Each trial consisted of a word appearing on the screen for 700 milliseconds, the variable delay for the inter stimulus interval was 500 to 600 ms followed by the stimulus image until they responded or until 1,200 milliseconds. Refer to Figure 2 for an illustration of the procedure. If the participants did not respond within 1,200 milliseconds a ‘trial timed out’ screen came on, this was then followed by the next trial. The task for he participant was to respond by pressing the corresponding key for matched or mismatched. Once the experiment was complete the participants were debriefed and allowed to wash and dry their hair.

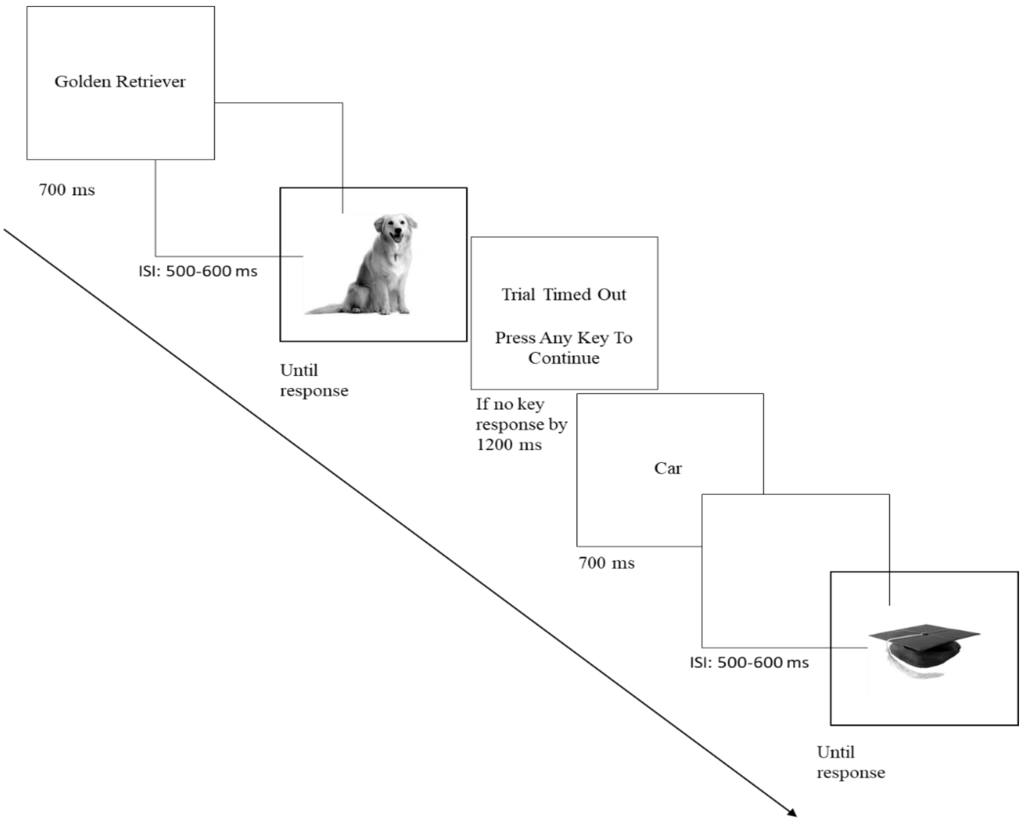

Figure 2. An illustration of the procedure

3.4 Electrophysiological Recording

An elastic cap containing 64 ActiCap electrodes was used to measure the brain voltage changes at the scalp. The placement of the cap was measured so that electrode CZ was placed halfway between the tragus on each ear and halfway between the inion and the central point of the eyebrows, this ensured the cap was in a similar position for every participant. The EEG traces were recorded using vision recorder and Acticap control was used. The impendence levels of the electrodes were between 0 and 10 kOhm. The impendence was brought down using electrode gel which was individually inserted into each electrode using a medical grade syringe. To minimize skin potential artefacts the skin around the ears, forehead and where the eye electrodes were placed was cleaned with a sterile alcohol wipe. In addition, eye electrodes were placed on the infra- and supra-orbital ridges of the left eye which measured eye blinks and any vertical eye movements. In order to measure horizontal eye movement's one electrode was placed at each outer corner of the left and right eye.

3.5 Electrophysiological Analysis

Analyzer 2 software was used to analyse the EEG data. The raw EEG data firstly went through topographic interpolation to account for any missing channels or any excessively noisy channels. To help interpolate the channels, notes made during testing were referred to. Once interpolated, a band-pass filter of 0.1Hz to 30Hz, order 4 was applied. This filter was chosen based on a literature review of the previous filter settings to determine the appropriate filter settings for the analysis of the N400 component (Angwin et al., 2014; Greenham & Stelmack, 2001). The high pass filter removed any slow drifts resulting from body movements. The low pass filter removed any high frequency noise. Ocular correction was then carried out in order to remove any noise created by eye movements and blinks. The continuous EEG data was then segmented into the 16 different conditions for example Subordinate Match 0° condition. The time markers for each segment was -200 milliseconds before the object appeared on the screen and 1,200 milliseconds after the stimulus image to capture responses, to correspond with that of the experiment. A DC Detrend was carried out followed by changing the sampling rate for all the segments to 500Hz from 250Hz. Artefact rejection was used to remove any unusual changes in the amplitude of the waveforms. The settings for the artefact rejection was set so the maximal allowed voltage was 50 µV, with the maximal allowed absolute difference of two values in one segment set to 200 µV. The amplitude criterion set was minimal allowed amplitude -80 µV and maximum allowed amplitude 80 µV. The criterion set for low level activity was 0.50 µV and the interval length was set at 100.00 ms. Baseline correction using the -200 ms pre stimulus time segment was applied before averaging the data. Baseline correction subtracts the mean distribution in the time interval from the ERP (Widmann, Schroger, & Maess, 2015). The averaged data for the individual participants and segments only included correct responses. Once all of the pre-processing was complete, the data from each condition for each participant was averaged together to create grand averages for each experimental condition.

The grand averages were then used to find the time period for the N400 component, the waveform for the central line electrodes which are Cz, C1, C2, C3, C4 and C5 was used. The central electrodes were specifically selected due to the effects seen in previous research on these electrodes (Hamm et al., 2002; Kutas & Federmeier, 2000, 2011). In addition to the grand averages, past research also influenced the time period. Within past research the time ranges used for analysis the N400 varied between 200 ms and 600 ms (Angwin et al., 2014; Hamm et al., 2002; Hurley et al., 2012; Khateb et al., 2010; Kutas & Federmeier, 2000). After deliberation the time period used was 250 ms to 580 ms, due to being the longest time range to show the N400 within all of the conditions on all electrodes within the central line within the data.

Once the time period was found, the peaks on the central line of electrodes were then exported using Analyzer2 software. The extracted peak data was then converted into an excel spreadsheet, where the participants data was organised ready for the final steps of the analysis. The data was organised in Excel using the macro function to bring all of the data for each electrode and condition for example Cz Basic Match 0˚ to run continuously on the horizontal of the spreadsheet, totalling 96 columns. The excel sheet was then opened using SPSS to conduct the final analysis.

4 Results

4.1 Behavioural Data

Reaction times in milliseconds (ms) for correct responses only were used for the analysis. Outliers were removed, if they were greater than 2.5 x standard deviation + mean, before averaging. An alpha value of .05 was used for all analysis. A 2 x 2 x 4 repeated measures ANOVA was carried out with category (basic or subordinate), match or mismatch and orientation (0˚, 60˚, 120˚ or 180˚) as the factors. The means and standard deviations of all 16 conditions can be found in Table 2. A significant main effect of match or mismatch was found $F(1, 26) = 69.84$, $p<0.0001$. As Figure 3 shows, it is clear that the matched words and pictures had quicker response times (M=630.17 ms SD=66.13) opposed to the mismatched words and pictures (M=667.08 ms SD=61.49). This shows that the reaction times for the mismatched word and picture pairs were significantly slower.

Table 2. Means and Standard Deviations of reaction times in ms for all 16 conditions.

	0˚		60˚		120˚		180˚	
	Basic	**Sub**	**Basic**	**Sub**	**Basic**	**Sub**	**Basic**	**Sub**
Matched								
Mean	630.59	603.35	644.42	617.79	645.52	627.27	650.04	622.37
SD	75.68	61.26	74.68	62.66	73.91	69.30	77.16	64.62
Mismatched								
Mean	639.00	675.11	649.71	688.01	656.78	693.02	658.99	676.00
SD	60.13	62.65	61.61	70.46	65.86	70.66	74.09	59.56

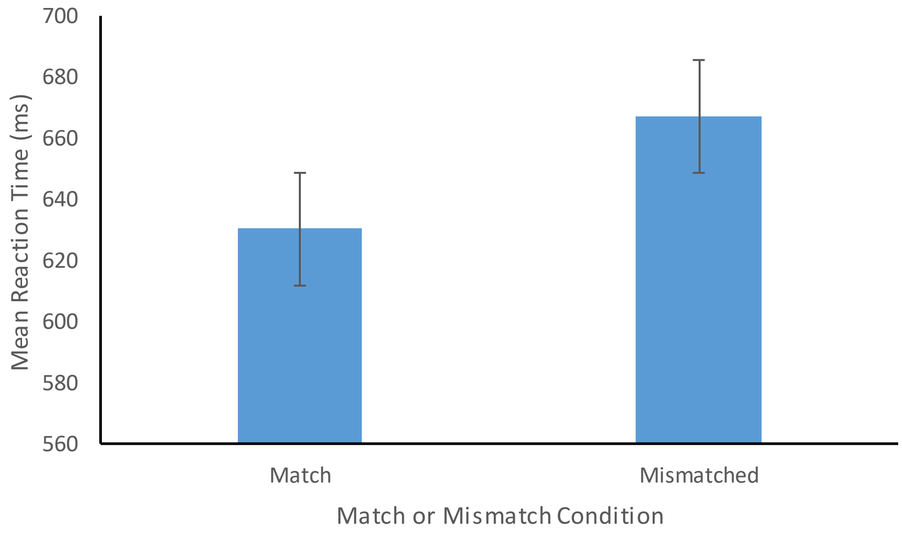

Figure 3. Mean reaction times in ms for the matched and mismatched conditions. All 16 conditions were collapsed across matched (8 conditions) and mismatched (8 conditions). The error bars show the standard error.

There was also a significant main effect of orientation, $F(3, 78) = 16.73$, $p<0.0001$. Figure 4 shows that the fastest reaction times were for the images displayed at 0˚ (M=637.01 ms, SD=60.28), then 60˚ (M=649.98 ms SD=63.79), 180˚ (M=651.85 ms SD=63.75) with 120˚ showing the longest reaction time (M=655.65 ms SD=65.82). A significant linear trend $F(1, 26) = 36.63$, $p<0.000$ was found in addition to a significant quadratic trend $F(1, 26) = 20.22$, $p<0.0001$. This is illustrated in Figure 4 as the response times linearly increase for 0˚, 60˚ and 120˚ and then slightly decrease for 180˚. An insignificant main effect of category $F(1, 26) = .63$, $p=.434$ was found.

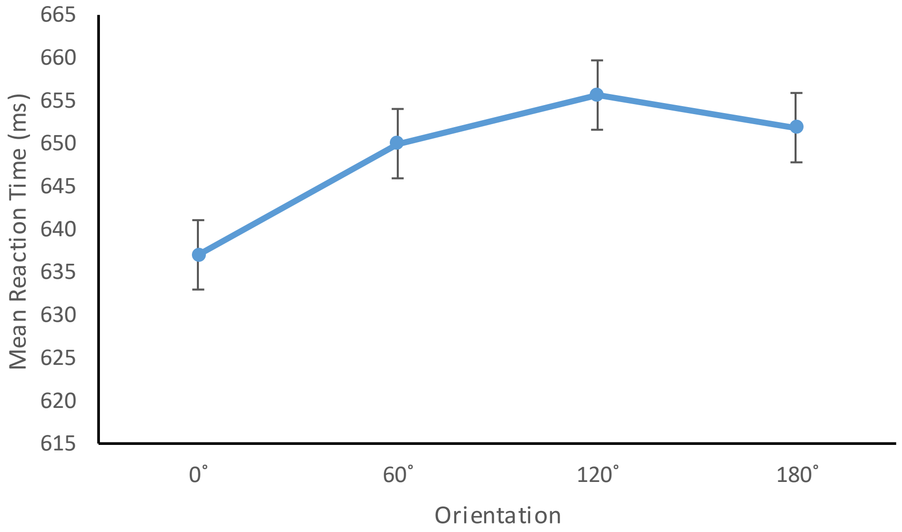

Figure 4. Mean reaction times in ms for the orientation that the pictures were displayed. All 16 conditions were collapsed across 0˚ (4 conditions), 60˚ (4 conditions), 120˚ (4 conditions) and 180˚ (4 conditions). The error bars show the standard error.

A significant interaction between category level and match or mismatch was found $F(1, 26) = 86.08$, $p<0.0001$. There is no requirement for a Bonferroni correction due to the hypothesis stating that basic category will be faster than the subordinate category across both match and mismatch. There is a greater difference between the response times for the subordinate category in both match (M=617.70 ms SD=64.25) and mismatch (M=683.04 ms SD=65.54) conditions, however the difference between the response times for the basic category in the match (M=642.64 ms SD=74.66) and mismatch (M=651.12 ms, SD=65.19) conditions are smaller, as can be seen in Table 2 and Figure 5. A paired samples t-test of basic versus subordinate in the match condition shows a difference of 24.94 ms 95% CI

[13.88, 36.00] which was significant t(26) = 4.64, p<0.0001 and represented a small-sized effect d=0.37. This finding goes against our hypothesis due to the subordinate category (M=617.70 ms SD=64.25) showing faster response times than the basic category (M=642.64 ms SD=74.66) in the match condition. A significant difference was also found between basic mismatched and subordinate mismatched conditions, with a difference of 31.91 ms 95% CI [20.97, 42.86], t(26) = 5.99, p<0.0001, and represented a medium-sized effect, d=0.51. This finding supports the hypothesis.

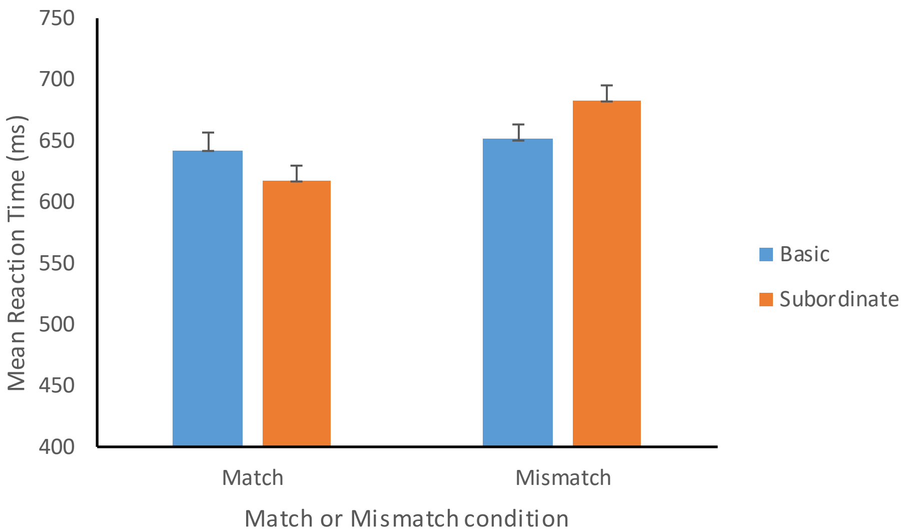

Figure 5. Mean reaction times in ms for the matched or mismatched conditions, at the category level of basic (blue bar) and subordinate (orange bar). All 16 conditions were collapsed across basic (8 conditions), subordinate (8 conditions) and match (8 conditions) or mismatch (8 conditions). The error bars show the standard error.

A significant interaction between category and orientation was found F(3, 78) = 2.74, p<0.05. From Figure 6 it can be seen that reaction times increases linearly from 0 to 120 degrees in both the basic and subordinate conditions but decreased substantially at 180 degrees for the subordinate condition. Linear and quadratic trends on orientation were tested separately for each category level. The linear trend for the basic category and orientation 0˚ to 180˚ was significant F(1, 26) = 21.90, p<0.0001. The quadratic trend was close to significance F(1, 26) = 3.45, p=.073. There was also a significant linear trend for basic category for orientations 0˚ to 120˚ F(1, 26) = 30.45, p<0.0001. The linear trend for the subordinate category and orientation 0˚ to 180˚ was significant F(1, 26) = 9.40, p<0.01. The quadratic trend was also significant for the subordinate category $F(1, 26) = 18.35$, $p<0.0001$. A significant linear trend was also found for the subordinate category for orientations 0˚ to 120˚ $F(1, 26) = 22.46$, $p<0.0001$, this is illustrated in Figure 6. There was no significant interaction between matched or mismatched and orientation $F(3, 78) = .78$, $p= .508$. The interaction between match or mismatch, category and orientation was not significant $F(3, 78) = .995$, $p=.400$.

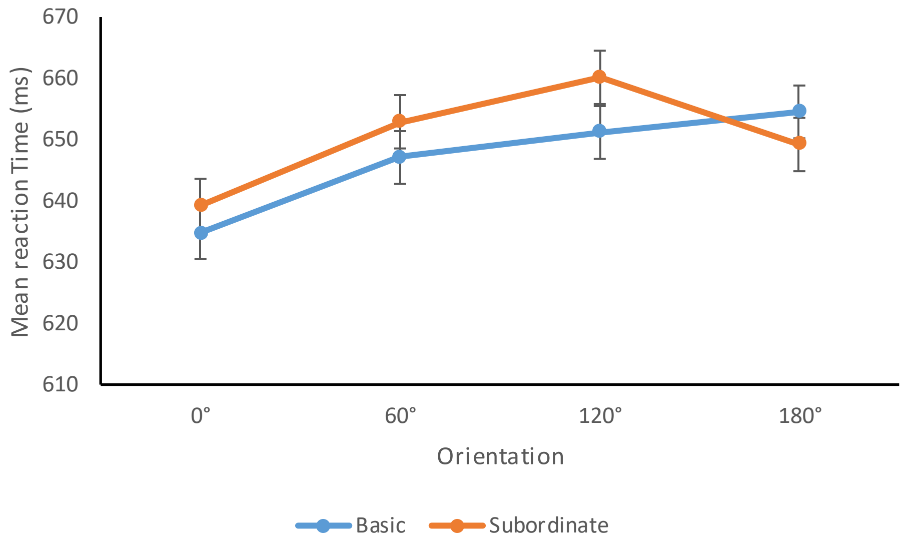

Figure 6. Reaction times for the different orientations for basic (blue line) and subordinate (orange line) categories. Collapsed across match and mismatch conditions. The error bars show the standard error.

Due to the unexpected results of the matched conditions having greater reaction times for the basic condition versus the subordinate condition, further analysis of the type of images used was carried out. It was possible that the finding was due to an outlier associated with a specific category of images. The reaction times across all orientations (0°, 60°, 120°, 180°) were summed together for the basic and subordinate categories for all of the different types of stimuli. The results are displayed in Table 3, as it can be seen the only two types of stimuli that supports our prediction that basic match is faster than subordinate match was the dog and car images. This means that the unexpected result cannot be explained by an anomalous result from a single category.

Table 3. Mean and Standard Deviations in ms for the matched conditions pooled across all orientations (0°, 60°,120°, 180°) for the different types of stimuli.

	Bird	Boat	Car	Dog	Fish	Hat	Jacket	Shoe	Truck
Basic									
Mean	702.21	699.79	663.98	596.06	631.90	608.05	645.06	641.12	776.13
SD	365.98	370.91	208.68	147.74	175.93	172.55	202.49	189.76	239.37
Subordinate									
Mean	631.38	651.40	672.99	600.65	601.52	578.26	625.66	598.02	750.82
SD	158.92	192.56	204.34	151.40	168.46	183.71	275.44	175.91	216.20

4.2 Accuracy Data

The mean percentage of correct responses is displayed in Figure 7. An ANOVA revealed a significant main effect of orientation $F(3, 78) = 6.17$, $P<.01$. A significant linear trend was found $F(1, 26) = 12.18$, $p<0.01$. The main effect of category was not significant ($p=.823$) and in addition, a non-significant main effect of match or mismatch ($p=.648$) was found.

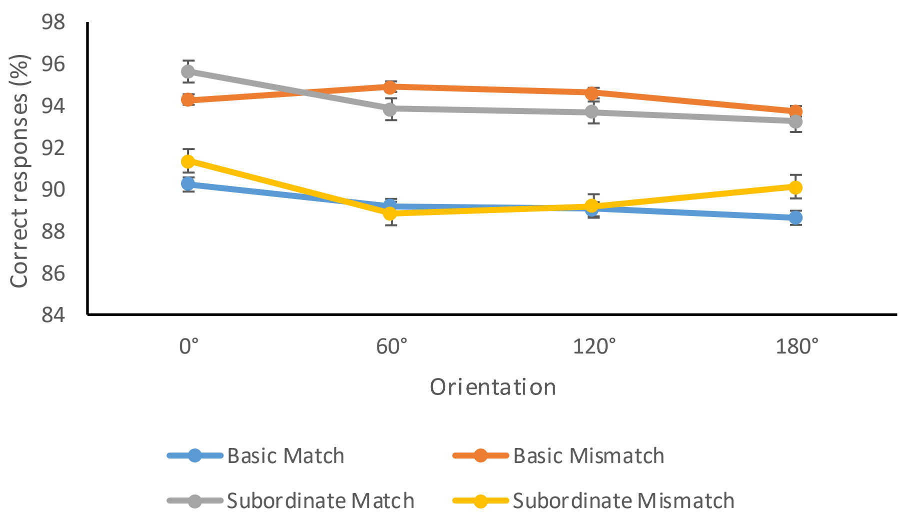

Figure 7. Percentage of correct responses for each condition. The error bars show the standard error.

A significant interaction between category and match or mismatch was found $F(1, 26) = 41.28$, $P<0.0001$. A paired samples t-test of subordinate and basic categories for match condition showed a significant difference of 4.82 95% CI [2.31, 7.34] $t(26) = 3.94$, $p<0.01$, representing a large sized effect $d=0.91$. A significant difference was found between basic and subordinate categories for the mismatch condition with a difference of 4.50 95% CI [2.95, 6.05] $t(26) = 5.98$, $p<0.0001$, showing a large-sized effect 1.11. The interaction between category and orientation failed to reach significance ($p=.065$). The interaction between match or mismatch and orientation was also not significant ($p=.606$). There was also no significant three-way interaction between category, orientation and match or mismatch ($p=.363$). The pattern of accuracy was consistent with the reaction times therefore there was no issue of speed accuracy trade off within the data.

4.3 Electrophysiological Data

The analysis for the N400 data was computed for the time window of 250 ms to 580 ms and the N400 data only included correct responses. The salient electrodes included in the statistical analysis were the central electrodes. To take into account sphericity assumption violations Huynh-Feldt eplson correction was employed (Huynh & Feldt, 1976). A 2 x 2 x 4 x 6 repeated measures ANOVA was carried out with the factors being, category (basic or subordinate), match or mismatch, orientations (0˚, 60˚, 120˚ or 180˚) and electrode (Cz, C1, C2, C3, C4 C5). There were no significant interactions between the factor of electrode and experimental conditions suggesting that the pattern of response associated with category, match/mismatch and orientation were similar across all 6 electrodes included in the analysis. With all the electrodes being central, this was not unexpected. This was the case for all analyses of the EEG data so effects of electrode will not be reported in the following section on the electrophysiological results

4.3.1 Category Effects

Mauchly's tests indicated that the assumption of sphericity had been violated (x^2 (0) = 0.00, $p<0.0001$, therefore degrees of freedom were corrected using the Huynh-Feldt estimates of sphericity ($\varepsilon=1.0$). The main effect of category was significant $F(1, 26) = 11.10$, $p<0.01$. The basic category conditions show a lower amplitude than the subordinate category condition, this can be seen in Figure 8. These support our hypothesis that basic category will show lower amplitudes than subordinate category.

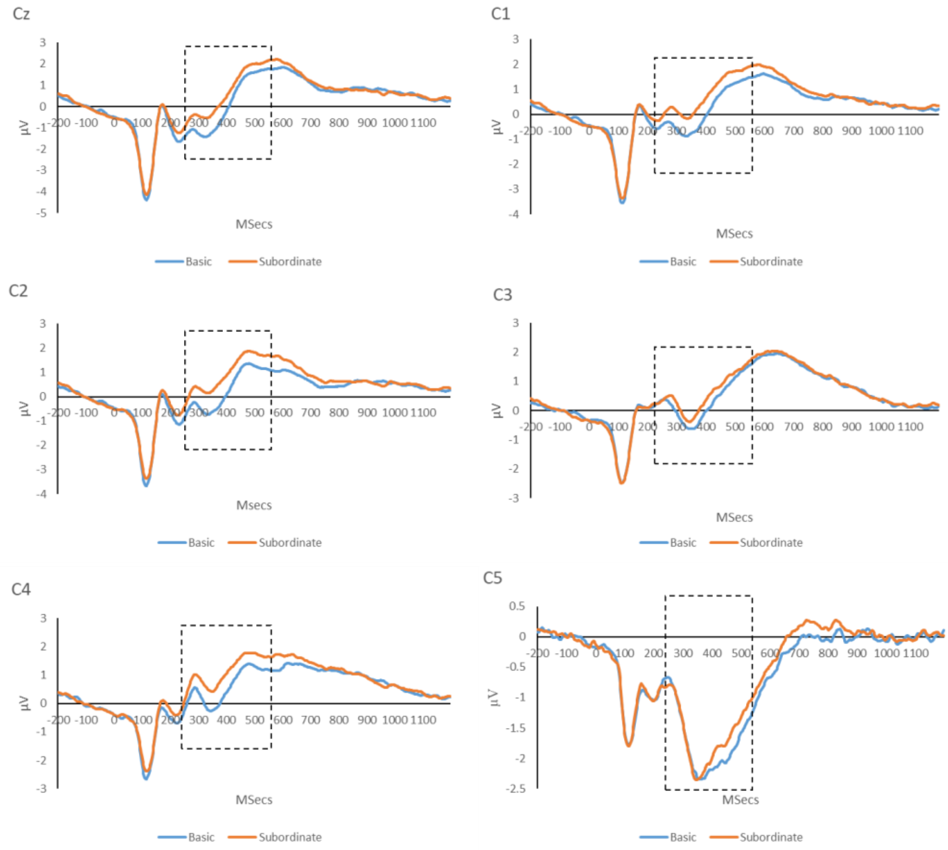

Figure 8. Mean amplitude of the N400 for each electrode for basic (blue line) and subordinate (orange line) conditions. All 16 conditions of matched, mismatched and orientations 0˚, 60˚, 120˚ and 180˚ were collapsed across basic or subordinate. The boxed area is the time window used to calculate mean amplitudes.

4.3.2 Match and Mismatch Effects

A significant main effect of match or mismatch was also found $F(1, 26)= 17.91$, $p<0.0001$. The mismatched conditions showed to have significantly lower amplitudes than the match conditions, this is illustrated in Figure 9. This supports our hypothesis that there would be lower amplitudes for mismatch conditions.

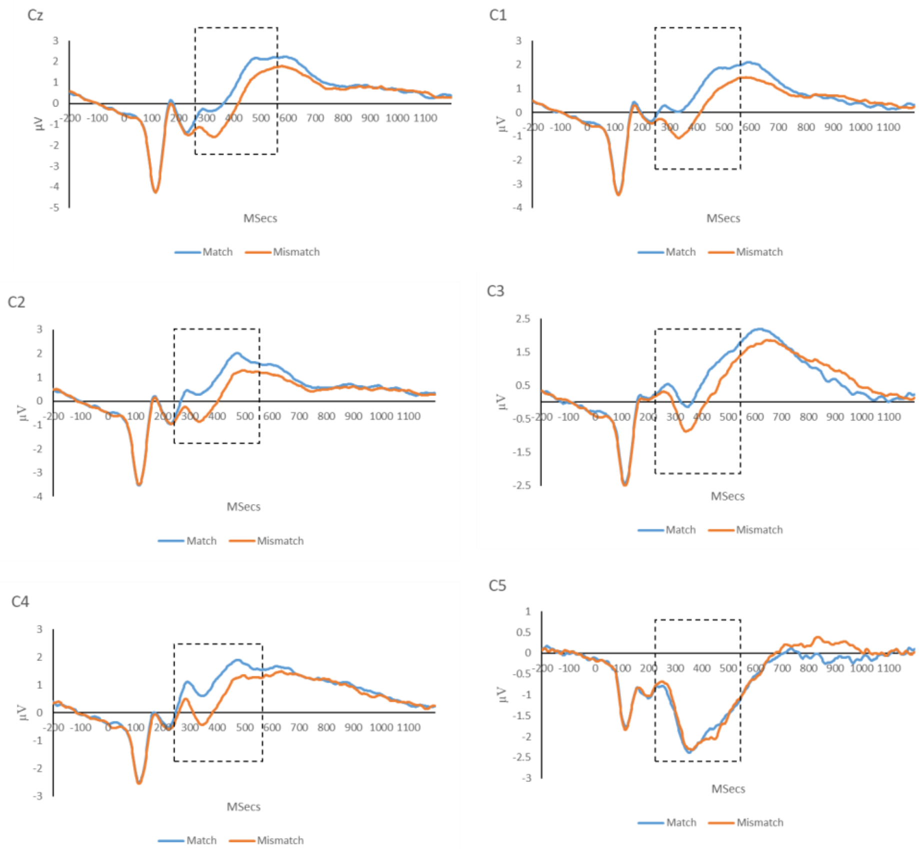

Figure 9. Mean amplitude of the N400 for each electrode for match (blue line) and mismatch (orange line) conditions. All 16 conditions of basic, subordinate and orientations of 0˚, 60˚, 120˚ and 180˚ were collapsed across match or mismatch. The boxed area is the time phase.

4.3.3 Category by Match and Mismatch effects

There was a trend to significance in the interaction between category and match or mismatch conditions $F(1, 26) = 2.86$, $p=.103$, as displayed in Figure 10. Based on the trend, t-tests were performed which showed that on all individual electrodes Cz to C5 the same significance pattern was found in which the basic category for match conditions showed a lower amplitude than subordinate match conditions. This can be seen in Figure 11 below. The means, standard deviations, P and T values for the electrodes Cz to C5 for the basic and subordinate categorization mismatch conditions can be seen in Table 4. As Table 4 shows there was no significant pattern between the categories for the mismatch conditions.

Table 4. Mean in µV, standard deviations and significant t and p values for electrodes Cz to C5. The mean values for the category and mismatch conditions were collapsed across orientations 0˚ to 180˚.

	Cz	C1	C2	C3	C4	C5
Basic Mismatch						
Mean	500.57	167.84	325.77	-31.36	232.26	-329.80
SD	836.99	804.00	844.37	607.01	482.16	731.19
Subordinate Mismatch						
Mean	511.12	207.02	377.12	21.85	305.48	-277.40
SD	648.56	686.23	742.72	564.20	506.67	536.73
T value	.124	.790	.967	1.419	1.747	.937
P value	0.902	0.437	0.343	0.168	0.092	0.357

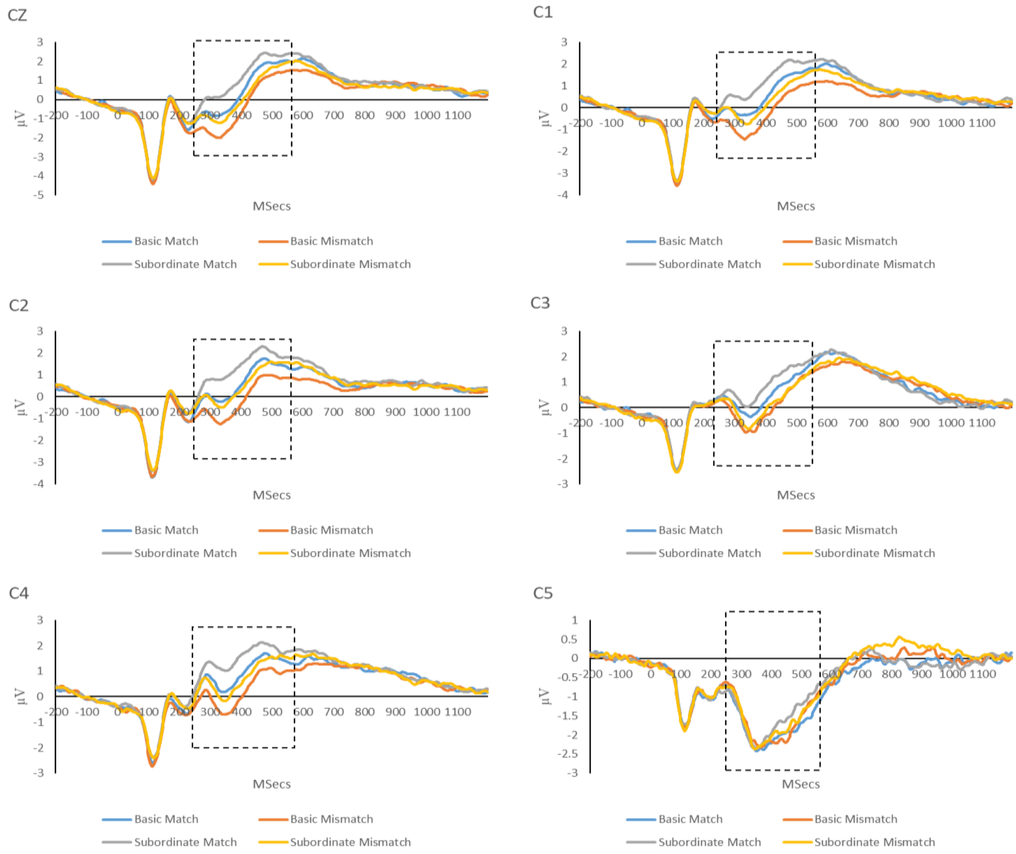

Figure 10. Mean amplitude of the N400 for each electrode for basic match (blue line), basic mismatch (orange line), subordinate match (grey line) and subordinate mismatch (yellow line) categorization conditions. All 16 conditions of basic or subordinate categorizations in match or mismatch conditions were collapsed across orientations 0°, 60°, 120°, 180°. The boxed area is the time phase.

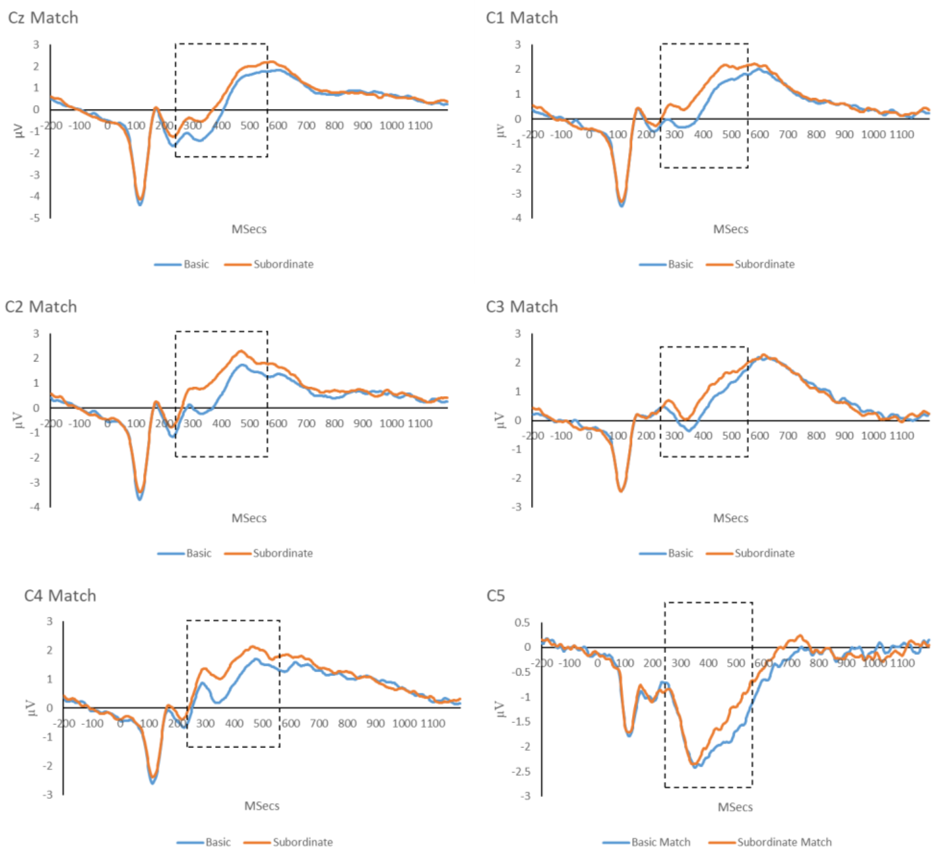

Figure 10. Mean amplitude of the N400 for each electrode for match basic (blue line) and subordinate (orange line) categorization conditions. All 16 conditions of basic or subordinate categorizations in match conditions were collapsed across orientations 0°, 60°, 120°, 180°. The boxed area is the time phase.

4.3.4 Category by Orientation effects

A significant interaction between category and orientation was found $F(2.34, 60.91) = 3.03$, $p<0.05$. Similar to the behavioural analysis, a significant quadratic trend was found for subordinate categorizations where pooled amplitudes increased from orientations 0˚ to 120˚ and decreased for 180˚. A significant quadratic trend was found for the subordinate category and orientation $F(1, 26) = 4.90$, $p<0.05$. By comparison there was an insignificant linear trend for basic categorization at orientations 0° to 180° $F(1, 26) = 3.18$, $p=.086$ and an insignificant quadratic trend $F(1, 26) = 1.33$, $p=.259$.

5 Discussion

The aim of the current research was to further investigate if the underlying neural networks of object recognition at a basic level of categorization is the same to that of subordinate level. It was hypothesised that the amplitude for the N400 would have greater negativity for the basic categorization in comparison to the subordinate categorization, due to the basic categorization having less semantic information and therefore reducing semantic expectation (Hamm et al., 2002; Kutas & Hillyard, 1984). The present findings supported this theory as the basic categorization for match conditions had a lower amplitude for the N400 than the subordinate match conditions. The N400 is sensitive to incongruity due to its effect on the semantic memory organisation, therefore a lower amplitude for the mismatch conditions was expected (Kutas & Federmeier, 2000). The current results supported the previous evidence as the mismatch conditions show a significantly lower amplitude for the mismatch conditions in comparison to the match condition. It was also hypothesised that orientation would have greater effects on the subordinate categorization than the basic categorization due to the basic categorization being orientation-invariant and not requiring a transformation in order to identify the object (Biederman, 1987; Corballis, 1988; Jolicoeur et al., 1984). One hypothesis that failed to be supported by the analysis was the hypothesis of the basic mismatch conditions showing significantly lower amplitudes to the subordinate mismatch conditions, due to our findings failing to show a significant difference between the basic and subordinate mismatch conditions.

The behavioural data analysis showed support for our hypothesis that basic level mismatch conditions would be faster than subordinate mismatch conditions, due to the basic level identification occurring first (Jolicoeur et al., 1984; Rosch et al., 1976). The reaction times for the orientations of 0° to 120° was linearly significant consistent with the theory that identification occurs through the shortest angular difference (Jolicoeur, 1985) and for 0° to 180° a significant quadratic trend was found as hypothesised. A further hypothesis supported was that match conditions were shown to have significantly faster reaction times than the mismatch conditions. It was also hypothesised that the basic match condition would have faster reaction times than the subordinate match reaction times however this was not supported by the behavioural analysis.

The finding of the significant quadratic trend for orientations 0° to 180° only at the subordinate categorization level and not at the basic level could also possibly be explained by the N400 being sensitive to task demands. Previous research has found the N400 to be vulnerable to the effects of task demands (Chwilla, Brown, & Hagoort, 1995). Kutas and Federmeier (2011) discuss how in word and sentence research when a word is used as a prime, the task demand has an effect. The N400 is shown to be larger when instructions called for semantic analysis. As the findings show for the current research, the amplitude of the N400 was significantly more negative for the subordinate category which requires a higher level of semantic processing. This higher level of semantic processing required for subordinate processing increases the difficulty of the task, in particularly when the stimuli are being displayed at varying angles. This is a possible explanation for the lack of significant differences between basic categorization and orientation as it has a lower task demand due to the stimuli being processed at a less semantically demanding level.

As Hamm and McMullen (1998) discussed objects displayed at varying orientations from their normal upright position at a basic level categorization do not require normalization. Normalization is the requirement of rotating an object to its normal upright position before it is identified as matching to a label by comparing it to stored representations. The EEG findings that the N400 showed a significant quadratic trend for orientation 0° to 180° for subordinate level categorization only supports Hamm and McMullen (1998). The N400 component is at the same time period as mental rotation occurs around 400 ms post-stimulus (Milivojevic et al., 2009). Therefore, the insignificant results at the basic level for the varying orientations shows mental rotation did not occur.

A further possible explanation to the electrophysiological analysis showing that the basic category had no effect of orientation in comparison to subordinate categorization is repetition of labels. The basic category stimuli only had 9 labels, whereas the subordinate category had 35 labels. There is evidence to show that the more exposure a participant has to a label and an orientated image, the less sensitive the reaction times are to the orientation (Jolicoeur, 1985). Participants in the current research were more exposed to the basic labels and image pairs due to on average each participant seeing the same basic label for 64 trials in comparison to the same subordinate label being seen on average only in 16 trials. The higher levels of practice for the basic category may be the cause of the non-significant effects of orientation. This explanation however is not supported by the behavioural data. The behavioural data shows a significant effect of orientation on the basic category and the subordinate category. The subordinate category did show a significant quadratic and linear trend whereas the basic category only showed a significant linear trend.

The current results provide additional support for the semantic priming effects for words preceding images as shown in previous research (Ganis et al., 1996). The greater repetition of basic labels may have strengthened and primed semantic associations so a lesser effect was displayed. The semantic priming effect is prominent in the results as the conditions which had a semantically meaningful word preceding the image had quicker reaction times. The matched conditions also showed to have higher amplitudes for the N400, implying there was a lesser effect on the N400 in comparison to the mismatched conditions. This also shows that the semantic priming effect is shown in the amplitude of the N400 component in addition to the relationship the behavioural data has with the ERP data.

Interestingly, the ERP findings of the effect of orientation only being apparent for the subordinate category support behavioural findings from previous research. Behavioural analysis has shown that the only categorization level that is sensitive to orientation is the subordinate level. This also supports the theory as discussed by Hamm and McMullen (1998) that orientation invariant representations also referred to as viewpoint independent representations, are made first before the normalization of the rotated objects image. The orientation invariant representations provide object identity (Biederman, 1987; Corballis, 1988). Basic level representations are ideal for the orientation invariant contact because it is the level in which the objects are first identified at (Jolicoeur et al., 1984; Rosch et al., 1976). Jolicoeur et al. (1984) concluded that objects are initially identified at a basic level and subordinate level identification only occurs once additional perceptual processing after basic level identification has taken place. Consistent with the assumption that normalization only occurs when spatial relations of an object parts is required.

The lack of significant effect of orientation had on the N400 at the basic level suggests that the N400 is effected similarly to orientation as reaction time is. The similarities between the behavioural data and the ERP data for orientation show that the behavioural data had a significant quadratic trend for orientation in which the reaction time for 120° increased from 60° and the reaction time for 180° decreased from that of 120°. The amplitude data also showed a significant quadratic trend for subordinate data in which for 120° the amplitude decreased, but for 180°, the amplitude increased. This shows a similar pattern across both analysis due to a decrease in mean amplitude being associated with an increase in reaction time.

It was also hypothesised that the basic match condition would have faster reaction times than the subordinate match reaction times however this was not supported by the behavioural analysis. The further analysis also showed that the hypothesis was only supported by two of the different types of stimuli, the dog and car images. Due to the basic category only having faster reaction times on two out of the nine different types of stimuli there would not be the justification to analyse the data without one type of image to investigate if a significant effect of basic showing faster reaction times could be found. The type of stimuli with the largest difference was the bird stimuli with a difference of 70.82 ms between the basic and subordinate category, see Table 3 for more details. This difference is not large enough to justify analysing the data without this category to test if there could be a change in significance of the categorization levels. Consequentially, the effect of basic showing slower reaction times requires a further explanation than it being caused by one particular type of stimuli.

The failing to support this hypothesis maybe explained as an effect of atypical categories. Previous research has found that for atypical categorizations (e.g. a penguin is an atypical example of a bird) subordinate categorizations display faster reaction times in comparison to basic categorizations. The greater differentiation of the atypical stimuli seems to give the subordinate processing the advantage over basic processing (Murphy & Brownell, 1985). Rips, Shoben, and Smith (1973) found that one particular concept that showed faster reaction time to subordinate categorization over basic categorization was the use of chicken as stimuli. In the current research chickens were used as a part of the wider basic category of bird in which the reaction times showed to support Rips, Shoben, and Smith (1973). The behavioural data showed that in the match conditions for the basic category identification of bird the reaction time summed across all orientations was a mean of 702.21 ms in comparison to the subordinate identification reaction time being a mean of 631.38 ms. Mack, Wong, Gauthier, Tanaka, & Palmeri (2009) also found that for atypical stimuli for birds had faster reaction times for subordinate categorization and in addition to this, they found that for the atypical dog category basic categorization were faster in comparison to subordinate categorization. This was also reflected in the current research as for the match conditions the reaction times showed that for the dog basic categorization the mean reaction time summed across all orientations was 596.06 ms in comparison to subordinate which was 600.65 ms.

Furthermore, research has also suggested that the level of expertise can affect the reaction times when categorizing at basic and subordinate levels. Evidence has shown that experts make subordinate level categorizations at the same speed as basic level categorizations, therefore showing basic and subordinate categorizations can be made independent of each other (J. W. Tanaka & Taylor, 1991). It has been suggested to be an entry-level shift which is when atypical stimuli and expert objects are first identified at the subordinate level and not the basic level (Mack et al., 2009). In respect to the current research, the basic categorizations that were found to be reacted to quicker on a subordinate level are stimuli that are well- known to individuals on an everyday basis but it cannot be assumed that any of the participants were experts in identifying these objects due to no measure of expertise being taken. In addition to this, it would be expected that if the effect was due to expertise it would also be seen in the mismatch conditions, however this was not the case as the basic categorizations had significantly faster reaction times than the subordinate categorizations within the mismatch conditions.

Further analysis could be carried out on this data given extra time to see if the nature of the images had a further effect, as evidence suggests that there is a distinction between the effect of processing of living and non-living stimuli. Behavioural data has previously shown that living stimuli elicit faster reaction times in comparison to non-living stimuli (Kiefer, 2001; Price & Humphreys, 1989). In contrast to this, naming and categorization tasks have found artificial stimuli to present faster reaction times than natural stimuli (Forde, Francis, Riddoch, Rumiati, & Humphreys, 1997; Hillis & Caramazza, 1991; LloydJones & Humphreys, 1997). The N400 has been shown to also be effected by the living and non-living dichotomy. In congruent conditions a less negative amplitude was shown for the non-living stimuli, contrasting to this in incongruent conditions the living stimuli elicited less negative amplitudes. These category specific effects on the N400 within the congruent and incongruent conditions are suggested to be reflecting a category specific differential enhancement (Kiefer, 2001). Devlin, Gonnerman, Andersen, and Seidenberg (1998) discuss that this may be due to the fact that non-living categories only share a small amount of features in result of this accepting a non-living stimuli as being a part of a superordinate congruent category is a highly demanding task in regards to semantic processing. Furthermore, with living stimuli it is more demanding to accept congruent categories as features in living objects are highly correlated between categories. The further analysis of the current findings to investigate the difference in the effects of living and non-living stimuli will allow further investigation into the living and non-living effects and illustrate how it effects the N400 in relation to orientation, congruity factors and categorization levels.

A limitation of the study is the use of some of the particular stimuli pairs used. Despite checks prior to running the experiment in regards to the suitability and understanding of the stimuli and which labels they correctly belong to, during the research some issues arose. It was observed and discussed throughout the research taking place that some participants had some confusion over the labels of the stimuli. In particular, many participants were unsure if a shark belonged to basic categorization of fish. This uncertainty could have led to incorrect responses or longer reaction times. If participants voiced their uncertainty during the experiment in regards to stimuli and their labels they were told the correct labels for the stimuli to avoid further confusion. In future studies more thorough testing of the images and labels used beforehand should be undergone and such images such as sharks should not be used in addition to this previously successful stimuli categories such as those used by Hamm and McMullen (1998) or Hamm et al., (2002) could be used.

Improving upon some of the limitations that arose during this research would be an advisable development of the research in the future. The main issue that needed addressing being the confusion over stimuli. In order to improve this in future research tried and tested stimuli datasets should be used that have not shown any problems of understanding. This will eradicate the issue of participants responding with avoidable incorrect responses or making the task demands for the specific categories larger due to the confusion, which could inadvertently effect reaction times and the amplitude of the N400.

The methodological issue of basic labels being repeated and practiced more than the subordinate labels could also be improved on within future research. The additional practice of the basic labels and stimuli is a possible cause for the lack of effect on the N400 when the stimuli was presented at varying orientations in the basic category , whereas a slight effect was seen for subordinate conditions. Recommendations for future studies is that the same amount of basic labels and subordinate labels are used. This may require a large amount of basic labels in order to get a variety of subordinate categories however this issue will have to be overcome during the design stages of future research.

To summarise, the N400 data showed that categorization and orientation interact with one another in such a way that basic level categorization is not significantly affected by orientation but subordinate categorization is affected, due to displaying lower amplitudes on the N400. This suggests that identifying objects at varying orientations on a subordinate level requires representation, whereas basic categorization does not. This requires further investigation as it could have also been possibly caused by the unequal amount of practice and the unavoidable different level of task demands. As found previously, the N400 was more negative for semantically incongruent conditions and for the less semantically demanding basic category. Behavioural findings support those previously found as faster response times were apparent for match conditions than mismatch conditions and orientations 0° and 180° versus 60° and 120°. The unexpected finding of basic match conditions having slower reaction times compared to subordinate categories has been found in previous experiments but additional investigation with future research is required to fully explain the reasoning behind this.

6 References

Anglin, J. (1976). Word, Object, and Conceptual Development. *Journal of Psycholinguistic Research, 5*(2), 229-230.

Angwin, A. J., Phua, B., & Copland, D. A. (2014). Using semantics to enhance new word learning: An ERP investigation. *Neuropsychologia, 59*, 169-178. doi:10.1016/j.neuropsychologia.2014.05.002

Biederman, I. (1987). Recognition-By-Components - A Theory Of Human Image Understanding. *Psychological Review, 94*(2), 115-147. doi:10.1037//0033-295x.94.2.115

Biederman, I., & Gerhardstein, P. C. (1995). Viewpoint-Dependent Mechanisms In Visual Object Recognition - Reply To Tarr And Bulthoff (1995). *Journal of Experimental Psychology-Human Perception and Performance, 21*(6), 1506-1514. doi:10.1037//0096-1523.21.6.1506

Biederman, I., Subramaniam, S., Bar, M., Kalocsai, P., & Fiser, J. (1999). Subordinate-level object classification reexamined. *Psychological Research-Psychologische Forschung, 62*(2-3), 131-153. doi:10.1007/s004260050047

Bressan, P., & Vicario, G. B. (1984). On Misoriented Letters. *Perception, 13*(6), 687-694. doi:10.1068/p130687

Bulthoff, H. H., & Edelman, S. (1992). Psychophysical Support For A 2-Dimensional View Interpolation Theory Of Object Recognition. *Proceedings of the National Academy of Sciences of the United States of America, 89*(1), 60-64. doi:10.1073/pnas.89.1.60

Chwilla, D. J., Brown, C. M., & Hagoort, P. (1995). The N400 As A Function Of The Level Of Processing. *Psychophysiology, 32*(3), 274-285. doi:10.1111/j.1469-8986.1995.tb02956.x

Collin, C. A., & McMullen, P. A. (2005). Subordinate-level categorization relies on high spatial frequencies to a greater degree than basic-level categorization. *Perception & Psychophysics, 67*(2), 354-364. doi:10.3758/bf03206498

Corballis, M. C. (1988). Recognition Of Disoriented Shapes. *Psychological Review, 95*(1), 115-123. doi:10.1037/0033-295x.95.1.115

Devlin, J. T., Gonnerman, L. M., Andersen, E. S., & Seidenberg, M. S. (1998). Category-specific semantic deficits in focal and widespread brain damage: A computational account. *Journal of Cognitive Neuroscience, 10*(1), 77-94. doi:10.1162/089892998563798

Fabre-Thorpe, M., Delorme, A., Marlot, C., & Thorpe, S. (2001). A limit to the speed of processing in ultra-rapid visual categorization of novel natural scenes. *Journal of Cognitive Neuroscience, 13*(2), 171-180. doi:10.1162/089892901564234

Forde, E. M. E., Francis, D., Riddoch, M. J., Rumiati, R. I., & Humphreys, G. W. (1997). On the links between visual knowledge and naming: A single case study of a patient with a category-specific impairment for living things. *Cognitive Neuropsychology, 14*(3), 403-458.

Ganis, G., Kutas, M., & Sereno, M. I. (1996). The search for "common sense": An electrophysiological study of the comprehension of words and pictures in reading. *Journal of Cognitive Neuroscience, 8*(2), 89-106. doi:10.1162/jocn.1996.8.2.89

Greenham, S. L., & Stelmack, R. M. (2001). Event-related potentials and picture-word naming: Effects of attention and semantic relation for children and adults. *Developmental Neuropsychology, 20*(3), 619-638. doi:10.1207/875656401753549834

Hamm, J. P., Johnson, B. W., & Kirk, I. J. (2002). Comparison of the N300 and N400 ERPs to picture stimuli in congruent and incongruent contexts. *Clinical Neurophysiology, 113*(8), 1339-1350. doi:10.1016/s1388-2457(02)00161-x

Hamm, J. P., & McMullen, P. A. (1998). Effects of orientation on the identification of rotated objects depend on the level of identity. *Journal of Experimental Psychology-Human Perception and Performance, 24*(2), 413-426. doi:10.1037/0096-1523.24.2.413

Hillis, A. E., & Caramazza, A. (1991). Category-Specific Naming And Comprehension Impairment - A Double Dissociation. *Brain, 114*, 2081-2094. doi:10.1093/brain/114.5.2081

Horton, M. S., & Markman, E. M. (1980). Developmental Differences In The Acquisition Of Basic And Superordinate Categories. *Child Development, 51*(3), 708-719. doi:10.1111/j.1467-8624.1980.tb02605.x

Hummel, J. E., & Biederman, I. (1992). Dynamic Binding In A Neural Network For Shape-Recognition. *Psychological Review, 99*(3), 480-517.

Hurley, R. S., Paller, K. A., Rogalski, E. J., & Mesulam, M. M. (2012). Neural Mechanisms of Object Naming and Word Comprehension in Primary Progressive Aphasia. *Journal of Neuroscience, 32*(14), 4848-4855. doi:10.1523/jneurosci.5984-11.2012

Huynh, H., & Feldt, L. S. (1976). Estimation of the box correction for the degrees of freedom from sample data in randomized block and split-plot designs. *Journal of Educational Statistics, 1*(1), 69-82.

Johnson, J. S., & Olshausen, B. A. (2003). Timecourse of neural signatures of object recognition. *Journal of Vision, 3*(7), 499-512. doi:10.1167/3.7.4

Jolicoeur, P. (1985). The Time To Name Disoriented Natural Objects. *Memory & Cognition, 13*(4), 289-303. doi:10.3758/bf03202498

Jolicoeur, P., Gluck, M. A., & Kosslyn, S. M. (1984). Pictures And Names - Making The Connection. *Cognitive Psychology, 16*(2), 243-275. doi:10.1016/0010-0285(84)90009-4

Key, A. P. F., Dove, G. O., & Maguire, M. J. (2005). Linking brainwaves to the brain: An ERP primer. *Developmental Neuropsychology, 27*(2), 183-215. doi:10.1207/s15326942dn2702_1

Khateb, A., Pegna, A. J., Landis, T., Mouthon, M. S., & Annoni, J. M. (2010). On the Origin of the N400 Effects: An ERP Waveform and Source Localization Analysis in Three Matching Tasks. *Brain Topography, 23*(3), 311-320. doi:10.1007/s10548-010-0149-7

Kiefer, M. (2001). Perceptual and semantic sources of category-specific effects: Event-related potentials during picture and word categorization. *Memory & Cognition, 29*(1), 100-116. doi:10.3758/bf03195745

Kiefer, M. (2002). The N400 is modulated by unconsciously perceived masked words: further evidence for an automatic spreading activation account of N400 priming effects. *Cognitive Brain Research, 13*(1), 27-39. doi:10.1016/s0926-6410(01)00085-4

Koriat, A., Norman, J., & Kimchi, R. (1991). Recognition Of Rotated Letters - Extracting Invariance Across Successive And Simultaneous Stimuli. *Journal of Experimental Psychology-Human Perception and Performance, 17*(2), 444-457. doi:10.1037//0096-1523.17.2.444

Kutas, M., & Federmeier, K. D. (2000). Electrophysiology reveals semantic memory use in language comprehension. *Trends in Cognitive Sciences, 4*(12), 463-470. doi:10.1016/s1364-6613(00)01560-6

Kutas, M., & Federmeier, K. D. (2011). Thirty Years and Counting: Finding Meaning in the N400 Component of the Event-Related Brain Potential (ERP). *Annual Review of Psychology, Vol 62, 62*, 621-647. doi:10.1146/annurev.psych.093008.131123

Kutas, M., & Hillyard, S. A. (1980). Reading Senseless Sentences - Brain Potentials Reflect Semantic Incongruity. *Science, 207*(4427), 203-205. doi:10.1126/science.7350657

Kutas, M., & Hillyard, S. A. (1984). Brain Potentials During Reading Reflect Word Expectancy And Semantic Association. *Nature, 307*(5947), 161-163. doi:10.1038/307161a0

LloydJones, T., & Humphreys, G. W. (1997). Categorizing chairs and naming pears: Category differences in object processing as a function of task and priming. *Memory & Cognition, 25*(5), 606-624. doi:10.3758/bf03211303

Low, A., Bentin, S., Rockstroh, B., Silberman, Y., Gomolla, A., Cohen, R., & Elbert, T. (2003). Semantic categorization in the human brain: Spatiotemporal dynamics revealed by magnetoencephalography. *Psychological Science, 14*(4), 367-372. doi:10.1111/1467-9280.24451

Mack, M. L., Wong, A. C. N., Gauthier, I., Tanaka, J. W., & Palmeri, T. J. (2009). Time course of visual object categorization: Fastest does not necessarily mean first. *Vision Research, 49*(15), 1961-1968. doi:10.1016/j.visres.2009.05.005

McMullen, P. A., & Jolicoeur, P. (1990). The Spatial Frame Of Reference In Object Naming And Discrimination Of Left-Right Reflections. *Memory & Cognition, 18*(1), 99-115. doi:10.3758/bf03202650

Mervis, C. B., & Crisafi, M. A. (1982). Order Of Acquisition Of Subordinate-Level, Basic-Level, And Superordinate-Level Categories. *Child Development, 53*(1), 258-266. doi:10.1111/j.1467-8624.1982.tb01315.x

Milivojevic, B., Hamm, J. P., & Corballis, M. C. (2009). Hemispheric dominance for mental rotation: it is a matter of time. *Neuroreport, 20*(17), 1507-1512. doi:10.1097/WNR.0b013e32832ea6fd

Milivojevic, B., Hamm, J. P., & Corballis, M. C. (2011). About turn: How object orientation affects categorisation and mental rotation. *Neuropsychologia, 49*(13), 3758-3767. doi:10.1016/j.neuropsychologia.2011.09.034

Murphy, G. L. (1991). Parts In Object Concepts - Experiments With Artificial Categories. *Memory & Cognition, 19*(5), 423-438. doi:10.3758/bf03199563

Murphy, G. L., & Brownell, H. H. (1985). Category Differentiation In Object Recognition - Typicality Constraints On The Basic Category Advantage. *Journal of Experimental Psychology-Learning Memory and Cognition, 11*(1), 70-84. doi:10.1037//0278-7393.11.1.70

Murray, J. E. (1997). Flipping and spinning: Spatial transformation procedures in the identification of rotated natural objects. *Memory & Cognition, 25*(1), 96-105. doi:10.3758/bf03197287

Parsons, L. M. (1987). Visual-Discrimination Of Abstract Mirror-Reflected 3-Dimensional Objects At Many Orientations. *Perception & Psychophysics, 42*(1), 49-59. doi:10.3758/bf03211513

Poggio, T., & Edelman, S. (1990). A Network That Learns To Recognize 3-Dimensional Objects. *Nature, 343*(6255), 263-266. doi:10.1038/343263a0

Price, C. J., & Humphreys, G. W. (1989). The Effects Of Surface Detail On Object Categorization And Naming. *Quarterly Journal of Experimental Psychology Section a-Human Experimental Psychology, 41*(4), 797-828.

Rips, L. J., Shoben, E. J., & Smith, E. E. (1973). Semantic Distance And Verification Of Semantic Relations. *Journal of Verbal Learning and Verbal Behavior, 12*(1), 1-20. doi:10.1016/s0022-5371(73)80056-8

Rosch, E., Mervis, C. B., Gray, W. D., Johnson, D. M., & Boyesbraem, P. (1976). BASIC Objects In Natural Categories. *Cognitive Psychology, 8*(3), 382-439. doi:10.1016/0010-0285(76)90013-x

Searle, J. A., & Hamm, J. P. (2012). Individual differences in the mixture ratio of rotation and nonrotation trials during rotated mirror/normal letter discriminations. *Memory & Cognition, 40*(4), 594-613. doi:10.3758/s13421-011-0172-2

Searle, J. A., & Hamm, J. P. (2017). Mental rotation: an examination of assumptions. *Wiley Interdisciplinary Reviews: Cognitive Science .Wiley Interdisciplinary Reviews: Cognitive Science* . 1 - 14.

Shepard, R. N., & Metzler, J. (1971). Mental Rotation Of 3-Dimensional Objects. *Science, 171*(3972), 701-&. doi:10.1126/science.171.3972.701

Tanaka, J., Luu, P., Weisbrod, M., & Kiefer, M. (1999). Tracking the time course of object categorization using event-related potentials. *Neuroreport, 10*(4), 829-835. doi:10.1097/00001756-199903170-00030

Tanaka, J. W., & Taylor, M. (1991). Object Categories And Expertise - Is The Basic Level In The Eye Of The Beholder. *Cognitive Psychology, 23*(3), 457-482. doi:10.1016/0010-0285(91)90016-h

Tarr, M. J. (1995). Rotating Objects To Recognize Them - A Case-Study On The Role Of Viewpoint Dependency In The Recognition Of 3-Dimensional Objects. *Psychonomic Bulletin & Review, 2*(1), 55-82. doi:10.3758/bf03214412

Tarr, M. J., & Kriegman, D. J. (2001). What defines a view? *Vision Research, 41*(15), 1981-2004. doi:10.1016/s0042-6989(01)00024-4

Tarr, M. J., & Pinker, S. (1989). Mental Rotation And Orientation-Dependence In Shape-Recognition. *Cognitive Psychology, 21*(2), 233-282. doi:10.1016/0010-0285(89)90009-1

Thorpe, S., Fize, D., & Marlot, C. (1996). Speed of processing in the human visual system. *Nature, 381*(6582), 520-522. doi:10.1038/381520a0

VanRullen, R., & Thorpe, S. J. (2001a). Is it a bird? Is it a plane? Ultra-rapid visual categorisation of natural and artifactual objects. *Perception, 30*(6), 655-668. doi:10.1068/p3029

VanRullen, R., & Thorpe, S. J. (2001b). The time course of visual processing: From early perception to decision-making. *Journal of Cognitive Neuroscience, 13*(4), 454-461. doi:10.1162/08989290152001880

Widmann, A., Schroger, E., & Maess, B. (2015). Digital filter design for electrophysiological data - a practical approach. *Journal of Neuroscience Methods, 250*, 34-46. doi:10.1016/j.jneumeth.2014.08.002

7 Appendix

UNIVERSITY OF Hull University of Hull Psychology Ethics Application

Ethics Checklist for Research Projects Involving Human Participants

NAME OF STUDENT/ASSISTANT (Supervised projects only). Katie Miles

RESEARCHER CLASSIFICATION MSc student

NAME OF RESEARCH SUPERVISOR Dr Mary-Ellen Large

TITLE OF PROJECT: The Neural Correlates of Categorizing Rotated Objects

NOTE This checklist should be completed by the investigator prior to beginning any research projects in which human participants will be employed. The checklist is intended to provide a general guide as to the ethical status of the project and whether or not a full application should be made to the Psychology Department Ethics Committee. It should be used in conjunction with the ethical guidelines published by the British Psychological Society. http://www.bps.org.uk/system/files/documents/code_of_ethics_and_conduct.pdf

Please complete all sections by ringing the appropriate answer.

RISKS

If you have answered **YES** in this section, make sure you provide enough details for the committee to assess your application.	
1) Do any aspects of the study pose a possible risk to participant's physical wellbeing (e.g. use of substances such as alcohol, extreme situations such as sleep deprivation, collecting data in potentially dangerous situations)? If **YES**, please specify: Click here to enter text.	NO
2) Are there any aspects of the study that participants might find humiliating, embarrassing, ego-threatening, in conflict with their values, or be otherwise emotionally upsetting?* If **YES**, please specify: Click here to enter text.	NO
3) Are there any aspects of the study that might threaten participants' privacy (e.g. questions of a very personal nature, observation of individuals in situations which are not obviously 'public')?* If **YES**, please specify: Click here to enter text.	NO
4) Does the study require access to confidential sources of information (e.g. medical records)? If **YES**, please specify: Click here to enter text.	NO
5) Could the intended participants for the study be expected to be more than usually emotionally vulnerable (e.g. medical patients, bereaved individuals)? If **YES**, please specify: Click here to enter text.	NO
6) Will the study take place in a setting other than the University campus or student accommodation? If **YES**, please specify: Click here to enter text.	NO

7) Does the researcher of this study require a Disclosure and Barring Service (DBS) check? This is required if research involves children or vulnerable adults, if required specify if obtained or applied for If **YES**, please specify (obtained or applied): Click here to enter text.	NO
8) Will the intended participants of the study be individuals who are not members of the University community? If **YES** describe who will be tested Click here to enter text.	NO
***Note**: if the intended participants are of a different social, racial, cultural, age or sex group to the researcher(s) and there is **any** doubt about the possible impact of the planned procedures, then opinion should be sought from members of the relevant group.	

2. DECEPTION

1) Does the study involve the use of non-trivial deception, either in the form of withholding essential information about the study or intentionally misinforming participants about aspects of the study? (See **Debriefing** section). If **YES** add additional information: Click here to enter text.	NO
If you have answered '**YES**' please make sure you address this issue in the informed consent and debriefing documents.	

3. INFORMED PARTICIPATION AND CONSENT

1) Participants in the study should be given written information outlining: 1. the general purpose of the study, 2. what participants will be expected to do 3. individuals' right to refuse or withdraw participation with impunity If **NO**, please specify: Click here to enter text.	YES
2) If the study involves physically unpleasant or emotionally upsetting procedures (e.g. viewing scenes of violence; working in loud noise), will participants be explicitly informed of this in writing?	N/A
3) Will all participants in the study be able to understand the information given and its implications for them?	YES
4) Will participants have an opportunity to ask questions prior to agreeing to participate?*	YES
5) Have appropriate authorities *(e.g. head teachers, classroom lecturers, shop managers)* given their permission for participants to be recruited and tested, or for data to be collected on their premises? If **YES** attach a copy of the letter or email granting permission at the end of this application form.	YES

6) Please complete an information sheet (Ctrl+click will take you to page 6 of this document) and consent form (Ctrl+click will take you to page 8 of this document)	

4. DEBRIEFING

1) Do the planned procedures include an opportunity for participants to ask questions and/or obtain general feedback about the study after they have concluded their part in it?*	YES
2) If deception has been used, does the procedure include a specific time for debriefing?	N/A
3) Please complete a debrief form (Ctrl+click will take you to Page 9 of this document) If you have answered **NO** to either question, make sure you address these issues in the informed participation/consent document and in the debriefing document	

5. ANONYMITY AND CONFIDENTIALITY

1) If anonymity has been promised, do the general procedures ensure that individuals cannot be identified indirectly?	YES
2) Have participants been promised confidentiality?*	YES
3) If confidentiality has been promised, do the procedures ensure that the information collected is truly confidential (e.g. questionnaire responses cannot be overseen by other participants; questionnaires are returned to the researcher in sealed envelopes)?	YES
4) Will non-anonymous data be stored in a secure place which is inaccessible to people other than the researcher? (N/A if study is anonymous)	YES
5) If participants' identities are being recorded, will the data be coded (to disguise identity) before computer data entry? (N/A if study is anonymous)	YES

* Note: 'N/A' would be appropriate for some purely observational studies.

6. DETERMINATION OF CLASSIFICATION

If you have answered 'YES' to any of the questions in Section 1 (risks), please select 'Exceptional' on the right	Exceptional
If you have answered 'YES' to the question in Section 2 (deception), please select 'Exceptional' on the right	Normal
If you have answered 'NO' to any of the questions in Section 3 (consent), please select 'Exceptional' on the right	Normal
If you have answered 'NO' to any of the questions in Section 4 (debriefing), please select 'Exceptional' on the right	Normal

If you have answered 'NO' to any of the questions in Section 5 (confidentiality), please select 'Exceptional' on the right	Normal

7. PROJECT CLASSIFICATION

If any of the boxes above in section 6 are answered with 'Exceptional', then the project should be classified as 'Exceptional'.

Normal NO

Exceptional Exceptional

Exceptional but a simple change to pre-approved study NO

Exceptional but only because the research involves research in schools or Outside organizations NO

Attached Documentation (these documents are mandatory)

- Information sheet YES
- Consent Form YES
- Debrief Form YES
- Permission Letter (if research is conducted in a school, or an institution outside of University of Hull) N/A

THE ETHICS APPLICATION NEEDS TO UPLOADED AT
http://psy.hull.ac.uk/Committees/Ethics/Checklist/

Researcher/Supervisor's Name Dr Mary-Ellen Large 06/11/2016
Students Name* Katie Miles Date 06/11/2016

RISK ASSESSMENT FORM – Department of Psychology University of Hull

Name Katie Miles Supervisor Dr Mary-Ellen Large

Title of Project: The Neural Correlates of Categorizing Rotated Objects

____

1. Where will the data be collected?

   In the Department __X___

   On the Campus _____

   Outside _____ Please state location ________________________________

2. Will any of the data collection take place outside of normal working hours?

   Yes _____ No __X___ Sometimes _____

   If yes conditions and precautions to be taken ______________________________________

   ____

   ____

3. Who will be the subjects (e.g. Students, Patients)? Students

4. Will Psychometric test material be used?

   Yes _____ No __X___

5. Does any procedure being used involve drugs, chemicals, blood or abrasions of the skin?

   Yes _____ No __X___

   If yes a COSHH assessment is required.

6. Please state test procedures to be used: The test procedure will be a computer based time task involving matching a word and an image. Electrophysiological measurements will be taken during the task but full training has been given by Dr Mary-Ellen Large and two years previous experience.

7. Will this project involve the carrying or movement of equipment?

Yes _____ No __X___

If yes please state what kind of equipment

____

____

8. Please state if there are any harmful effects in the test procedure or the administration of test materials for the subject or experimenter and what precautions will need to be taken

There is no harmful effects to the participants or the experimenter.

9. State training or instruction received for all methods or procedures in this project

Training on how to operate and set up the EEG equipment and software was required and completed.

Supervisors Assessment - This is a low Risk experiment – there is little risk to the researcher – it will be all carried out on computer

Student signature ____ Date 06/11/16

Supervisor signature _ ME Large ______________________________ Date 06/11/16

A PROJECT SHOULD NOT COMMENCE UNTIL A RISK ASSESSMENT HAS BEEN CARRIED OUT

Title: The Neural Correlates of Categorizing Rotated Objects

Researcher name: Dr Mary-Ellen Large, Katie Miles

Purpose of Study
The purpose of this study is to examine how the viewpoint and categorization of everyday objects effect the neural correlates.

Procedures
This study will require you to complete a practice task and a main computer task in which they will judge if the object in the image and the preceding word match. Some of the trials will include images displayed at different orientations. ERP signals are being measured using an electrode cap which will be placed on your head this will measure the activity of your brain during the tasks. Some electrodes will also be placed around the eyes. Electrical activity created by your brain in addition to reaction times and accuracy will be measured.

How much of your time will participation involve?
The experiment should take approximately two hours.

Will your participation in the project remain confidential?
If you agree to take part, your name will not be recorded on the questionnaires and the information will not be disclosed to other parties. Your responses to the questions will be used for the purpose of this project only. You can be assured that if you take part in the project you will remain anonymous.

Payment
You are free to withdraw from the research at any point without losing the benefit of your credit. Participation will be voluntary but you will receive course credits for your participation.

Potential Risks and Ethical Consideration
The recording of your EEG, which is the natural electric charges on your scalp, will not result in any discomfort. In rare cases there may be a temporary and quickly reversible skin irritation or redness. Conductive gel and paste will be applied on the electrodes. This creates a cold sensation but there is no known harm to this. The gel can be washed off thoroughly after the experiment. Performing the task requires the completion of a number of experimental blocks, however, there are numerous rest periods throughout the experiment. The researcher has undergone training with Dr. Mary-Ellen Large and has previous experience in the use and administration of EEG.

Benefits
You gain the experience and insight into a Psychology research experiment, as well as being able to ask any questions you may have.

What happens now?
If you are interested in taking part in the study you are asked to complete and sign the consent form. Then you will be given more specific instructions. Do not sign if you do not wish to take part. Please feel free to ask any questions that you may have.

Contact for Further Information
Dr Mary-Ellen Large: M.Large@hull.ac.uk

INFORMED CONSENT FORM

The Neural Correlates of Categorizing Rotated Objects
Investigators: Katie Miles and Dr Mary-Ellen Large

Department of Psychology, University of Hull

The participant should complete the whole of this sheet himself/herself. Please cross out as necessary

- Have you read and understood the participant information sheet YES/NO
- Have you had the opportunity to ask questions and discuss the study YES/NO
- Have all the questions been answered satisfactorily YES/NO
- Have you received enough information about the study YES/NO
- Do you understand that you are free to withdraw from the study: at any time without having to give a reason YES/NO
- Do you agree to take part in the study YES/NO

This study has been explained to me to my satisfaction, and I agree to take part. I understand that I am free to withdraw at any time.

Signature of the Participant. . . . .

Date. . . . .

Name (in block capitals) . . . .

I have explained the study to the above participant and he/she has agreed to take part.

Signature of researcher . . . .

Date. . . . .

Debriefing information (Let participant take this with them)

Title: The Neural Correlates of Categorizing Rotated Objects

Name of Principal Investigator and Researcher Dr Mary-Ellen Large Katie Miles

Background and Research Question:
Previous research has found that humans are extremely fast at processing images and extracting categorical information. Electrophysiological studies have found that the time course of visually categorizing an image starts within 150 ms after the presentation of an image. The N400 component which occurs around 400 ms is associated with semantic incongruity. It has also been shown that more specific categorization for example identifying a dog as a Labrador takes longer to identify, with basic categorization occurring fastest for example identifying the image as a dog.

The purpose of the study is to investigate the time course of visual object categorization when objects are displayed at varying orientation. The excellent temporal resolution of EEG allows us to measure the early (150 ms) and late (600 ms) time periods of object categorization.

Method and Design:
We measured differences in the reaction time to match a word to an image of an object presented at varying orientations (0°, 60°, 120°, 180°). On some trials the word and image did not match. The experiment used a within-subject design and consisted of factors of category (Basic level categorization, Subordinate level categorization), orientation (0°, 60°, 120°, 180°) and match (match or mismatch). We measured the electrophysiological signals so we could measure the effects of orientation on object categorization.

Anticipated findings:
The study is partially exploratory. It is expected however that mismatch conditions will show more negative amplitudes on the N400 component due to higher levels of incongruity. In addition to mismatch amplitudes varying in response to categorization levels and orientation, with the amplitude being more negative for basic level of categorization in comparison to subordinate level of categorization. The effect orientation will have on amplitudes is uncertain. It is expected that reaction times will show basic categorizations to be faster than subordinate categorization and match to be faster than mismatch. It is also expected that images displayed at 0° will show the fastest reaction time with it slowing the further the angular difference.

Further information: For any further information you can contact Dr. Mary-Ellen Large.
If you have any complaints, concerns, or questions about this research, please feel free to contact, Dr. Mary-Ellen Large M.Large@hull.ac.uk.

Details on EEG methods
The EEG methods component of this research is covered by Mary-Ellen Large's approval for this technique.

The risks involved are minimal and relate to the length of the experiment due to the technique and high volume of trials it can be boring for the participant. The EEG requires water based, non-allergic conductance gel to be placed between the electrode and the scalp. A blunt syringe will be used to insert the gel, forceful use of the syringe may cause scratches however I am experienced in the method which will avoid this happening. The participant will need to wash out the gel before leaving in the facilities provided by the department and they will have the facilities to dry their hair before they leave the lab.
I have been trained previously by Dr. Mary-Ellen Large to be able to use the EEG equipment safely. In addition I have over a years' experience in using EEG for research purposes within the laboratory set up.

Participant Screening Information
For experimental reasons we need some more generic details about our participants. For this reason, we really appreciate if you can fill the following form. The nature of the EEG neuroimaging technique means that there are some restrictions on the suitability of participants, which relate to your health as well as some practical considerations such as hair type. If you have any questions about the requested information please contact Dr Mary-Ellen Large.

Anonymity/Confidentiality
Any information concerning you and your participation in this study will be kept private and confidential. If information about you is published it will be in a form such that you cannot be recognized. The code linking names and numbers will be kept in a locked filing cabinet and will only be looked at by research stuff under the strict supervision of Dr. Mary-Ellen Large. Data for the study will be used in scientific reports, but no names or identifying information will be included in these reports.

Gender________
Date of Birth____
Years of Education____
Left/Right Handed ____

Are you currently taking any medication? Yes No
If yes, please give details.
____
____

Have you ever had a stroke? Yes No
If yes, please give details.
____
____

Have you ever had a head injury? Yes No
If yes, please give details.
____
____

Have you ever had seizures, convulsions? Yes No
If yes, please give details.
____
____

Do you have or have you had Alcohol or Drug Usage problems? Yes No
If yes, please give details.
____
____

Do you suffer from epilepsy? Yes No ____

BMI ________________________________(to calculate your BMI go to http://www.bbc.co.uk/health/tools/bmi_calculator/bmiimperial_index.shtml)

Hair type

☐ Short ☐ Medium ☐ Long ☐ Straight ☐ Curly ☐ Tightly curled

☐ Thick ☐ Fine ☐ Normal