AFFORDANCES AND THEIR INHIBITION

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I. ABSTRACT

The purpose of the thesis is to look at the activation and inhibition of motor affordances and explore the functioning of affordances. In experiment 1, the main goal is to collect a norm we call "grasp orientation agreement" (GOA) which indicates to which extent people agree to pick up an object with either the left or the right hand. In turn, the first purpose is to employ the stimuli with the greatest agreement in the following experiments of the thesis. The second purpose is to assess the GOA separately for the three different grip categories proposed by Vainio [1]. Experiment 2 demonstrates the affordance effects induced by the objects that were selected in Experiment 1. Here, there is a categorization task where subjects must classify the object stimuli (oriented to the left or right in regards to their handle or graspable part) as kitchen utensils or tools [2]. In terms of reaction time (RT), the results fit with the anticipated affordance effects involving facilitation: the average RT is significantly shorter for congruent trials (response hand is on the same side as the object's orientation) compared to incongruent trials. In terms of error rate, there is no significant difference between congruent and incongruent trials. Next, the goal of the 'arrow experiment' (experiment 3) and the 'dot experiment' (experiment 4) is to look at the results in terms of the temporal features of the affordance effect and, more specifically, to assess the time course of the activation and inhibition of affordances. Here, a prime object oriented to the left or right is followed by a blank screen (with different prime-target SOAs) which occurs prior to a central arrow target pointing to the left or right or a lateralized dot target at the left or right of the screen to which the subject responds with the left or right hand, respectively. A compatible trial implies that the hand (left or right) that would be used to grasp the prime object corresponds to the side of the target (i.e. the direction of the central arrow or the location of the lateralized dot to the left or right). An incompatible trial would imply that they are on opposite sides. Moreover, the term positive compatibility effect (PCE) implies that the RT is shorter or the error rate is less for compatible trials compared to incompatible trials. On the other hand, the term negative compatibility effect (NCE) implies that the RT is shorter or the error rate is less for incompatible trials compared to compatible trials. In our arrow experiment, in terms of RT, we observe NCEs at all SOAs. However, the NCE seems to decrease with increasing SOA and we can postulate that beyond the 600 ms SOA (the longest SOA assessed in our experiment), the NCE may potentially turn into a PCE. In terms of error rates, for all SOAs, we have a significant NCE except for the 300 and 600 ms SOAs where the NCE is not significant. In the dot experiment, in terms of RTs, there is a PCE

at short SOAs (although it is not statistically significant) which turns into an NCE at long SOAs. In terms of error rates, there is no significant interaction between SOA and compatibility and no significant main effect of compatibility. In summary, we have assessed the time course for affordances and their inhibition in two different experimental conditions (the arrow and dot experiments). Our results may be extrapolated to the analysis of schizophrenic patients who may show delusional or false beliefs due to a decreased capacity for inhibiting such beliefs. In turn, the experimental conditions we employed for healthy participants may be repeated with schizophrenic patients in whom we may expect decreased inhibition of affordances.

RÉSUMÉ

Le but de cette thèse est d'examiner l'activation et l'inhibition des affordances motrices et d'explorer le fonctionnement des affordances. Dans l'expérience 1, le but principal est d'amasser une norme qu'on appelle 'accord de l'orientation de la prise' (AOP) qui indique jusqu'à quel point les gens sont d'accord de poigner l'objet avec la main gauche ou la main droite. Ainsi, le premier but est d'utiliser les stimuli avec le plus haut accord dans les expériences subséquentes de la thèse. Le deuxième but est d'examiner le AOP séparément pour les trois sortes de catégories de prise suggérées par Vainio [1]. La deuxième expérience démontre les effets d'affordances induis par les objets qu'on a sélectionné dans la première expérience. Ici, il y a une tâche de catégorisation où les sujets doivent classifier les stimuli d'objets (orientés vers la gauche ou la droite par rapport à leur manche ou la partie par laquelle ils sont pris) dans l'une de deux catégories : 1) ustensiles de cuisine ou 2) outils [2]. En termes de temps de réaction (TR), les résultats concordent avec les effets d'affordances anticipés qui impliquent une facilitation : le temp de réaction moyen est significativement plus court pour les épreuves congruentes (où la main de réponse est du même côté que l'orientation de l'objet) que les épreuves incongruentes. En termes des taux d'erreurs, il n'y a pas de différence significative entre les épreuves congruentes et incongruentes. Ensuite, le but de 'l'expérience de flèche' (expérience 3) et de 'l'expérience de point' (expérience 4) est d'analyser les résultats en termes des attributs temporels de l'effet d'affordance et, plus spécifiquement, la progression temporelle de l'activation et l'inhibition des affordances. Ici, l'objet prime orienté vers la gauche ou la droite est suivi par un écran vide qui lui est suivi par une cible: 1) une flèche qui pointe vers la gauche ou la droite ou 2) un point latéralisé à gauche ou à droite de l'écran. Ensuite, le sujet répond avec la main gauche ou la main droite, respectivement. Il y a des intervalles différents entre le prime et la cible que l'on appelle SOAs. Une épreuve compatible

implique que la main (gauche ou droite) qui serait utilisée pour poigner l'objet prime correspond au côté de la cible (c.à.d. la direction de la flèche centrale ou la location du point latéralisé à gauche ou à droite). Une épreuve incompatible implique qu'ils sont sur des côtés opposés. De plus, le terme 'effet de compatibilité positive' (ECP) implique que le TR est plus court et le taux d'erreurs est plus bas pour des épreuves compatibles comparées à des épreuves incompatibles. En contraste, le terme 'effet de compatibilité négative' (ECN) implique que le TR est plus court et le taux d'erreurs est plus bas pour des épreuves incompatibles comparées à des épreuves compatibles. Dans l'expérience de flèche, en termes de TR, on observe des ECNs à tous les intervalles (SOAs). Par contre, le ECN semble décroitre quand le SOA augmente et on peut postuler qu'au-delà du SOA de 600 ms (le SOA le plus long qu'on a examiné dans notre expérience), le ECN peut potentiellement devenir un ECP. En terme du taux d'erreurs, pour tous les SOAs, on a un ECN significatif sauf pour les SOAs de 300 et 600 ms où le ECN n'est pas significatif. Dans l'expérience de point, en termes de TRs, il y a un ECP aux SOAs courts qui n'est pas statistiquement significatif et qui devient un ECN aux SOAs longs. En termes des taux d'erreurs, il n'y a pas d'interaction significative entre le SOA et la compatibilité et pas d'effet de comptabilité significatif. En résumé, on a examiné la progression temporelle des affordances et leurs inhibitions dans deux conditions expérimentales différentes (l'expérience de flèche et l'expérience de point). Nos résultats peuvent être extrapolés à l'analyse des patients schizophréniques qui peuvent montrer des croyances fausses ou des délusions à cause d'une capacité moindre pour inhiber de telles croyances. En conséquence, les conditions expérimentales qu'on a utilisées pour des participants en santé peuvent être répétées pour des patients schizophréniques pour lesquelles on peut s'attendre à une inhibition des affordances diminuée.

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III. Contribution of Authors

I am the only author that worked on this thesis.

IV. INTRODUCTION

Every day life stimuli are known to activate many types of representations including affordances, namely, action tendencies. For example, a cup may lead to the affordance of picking up the cup and drinking from it. These activations are automatic and pre-conscious. Many of them are inappropriate and should not be integrated into the representation of the situation or affect behavior. These representations might then be subsequently inhibited. The general aim of the present study is to look at the activation and inhibition of motor affordances and explore the functioning of affordances.

There is a summary of notions linked to affordances in the review section of this thesis. In addition, we carried out four distinct experiments and looked only at behavioral results. For the first experiment, the central purpose was to assess a norm we call "grasp orientation agreement" (GOA) which reflects the degree to which subjects were in agreement in regards to whether they would use either the left hand or the right hand to pick up an object. We employed a set of stimuli from the Bank of Standardized Stimuli (BOSS) [3, 4], chose the pictures of objects that are suitable in terms of some precise criteria and instructed the subjects to choose the hand with which they would pick up and use the object. The main goal was to use the stimuli with the highest agreement in the thesis' subsequent experiments.

We categorized all items as having a left or right orientation of their handle or graspable part. The subjects (mostly right-handed) were instructed to decide whether they would use their right hand or left hand if they had to pick up the object as fast as possible. There was a partiality for using the right hand [5]. The semantic categories with the highest amount of distinct concept objects (defined in the stimuli section of experiment 1) were the kitchen utensils and tools categories [3, 4].

This experiment had an additional exploratory goal which was to evaluate the GOA in an isolated manner for the three grip types that Vainio et al. suggest in their study [1]. Items from every different grip type had properties in regards to which the response code associated to the orientation can be retrieved in a different way [1]. The inclusion of three categories of items permitted the evaluation of whether an object's orientation can be distinguished from different object characteristics like the main axis of elongation or the handle location [1]. This could be an essential aspect in the orientation effect [1]. In addition, we examined our findings with respect to the semantic categories since it is not solely the kind of grip that could have an impact on the findings [1, 6, 7]. In fact, the semantic kinds of items could have an impact as well on the findings [1, 6, 7]. Moreover, there could be an association between the kind of semantic object and the kind of grip. For example, certain items involved a greater propensity of including handles. Also, certain kinds of handles could be overrepresented in certain categories of items in terms of semantics. Therefore, the findings did not solely permit us to recognise the items with a large GOA for the following experiments and future studies but also permit us to evaluate the factors that impact the GOA like the categories of items in terms of semantics, their kind of grip and their familiarity.

The second experiment was designed to test the affordance effects induced by the objects that were chosen from the first experiment. The second experiment was a categorization task where subjects must classify the object stimuli (selected from the first experiment with a hand agreement of 10/12 or more) as kitchen utensils or tools [2]. In this second experiment, the object stimuli on the screen may be oriented to the left or right in regards to their handle or graspable part (i.e. they can be grasped with the left or right hand, respectively). Although the object on its own was task-relevant since the subjects had to classify the object, its orientation was not at all task-relevant. We told subjects to use their right hand by pressing 'm' when a kitchen utensil appeared and to use their left hand by pressing 'z' when a tool appeared. The letter 'm' is at the right of the keyboard where as the letter 'z' is at the left of the keyboard. The congruent trial involved the fact that the response hand and the orientation of the object's handle or graspable part were on the matching side [2]. On the other hand, the response hand and the object's orientation were on different sides for the incongruent trial [2]. In terms of reaction time (RT), the results fitted with the anticipated affordance effects involving facilitation: the mean RT was significantly less for congruent trials in contrast to incongruent trials [2, 5]. In terms of error rate, there was no significant difference between congruent and incongruent trials. Hence, we can conclude in terms of RTs that the affordance effects were induced when employing the objects that were chosen in Experiment 1.

The two next experiments are referred to as the 'arrow experiment' (experiment 3) and the 'dot experiment' (experiment 4). The purpose here was to assess the findings in regards to the affordance effect's temporal features and, more specifically, to evaluate the time course of the activation and inhibition of affordances. In the arrow experiment, we presented images of graspable objects which according to their orientation and based on experiment 1, tend to be grasped with either the left hand or the right hand. Each image presentation was followed by a blank screen with 8 different SOAs (0 ,10, 16 ,32 ,60, 100, 300 and 600 ms). After the blank screen, an arrow was presented centrally pointing to the right or left to which the subjects had to respond with the right or left hand, respectively. Note that here, not only was the prime object's orientation irrelevant to the task but the prime object itself was also task-irrelevant since subjects responded to a target arrow. A compatible trial implied that the handle (or graspable part) of the prime object was on the matching side to the direction of the central target arrows. In incompatible trials, they were on different sides. In what is called a "positive compatibility effect" (i.e. a PCE), the RTs and error rates should theoretically both be lower for compatible trials in contrast to incompatible trials because the response to the target is facilitated by an affordance activation due to the prime [8]. In what is called a "negative compatibility effect" (i.e. an NCE), the RTs and error rates should both be lower for incompatible trials in contrast to compatible trials because the response to the target is hindered by an affordance inhibition due to the prime [8]. In our arrow experiment, in terms of RT, we found NCEs for every SOA (i.e. time delays between the prime and target). Yet, there appeared to be a reduction in the NCE as the SOA rises and we can hypothesise that above the SOA of 600 ms (i.e. the greatest SOA we employed), the NCE could possibly become a PCE. In terms of error rates, for all SOAs, we had a significant NCE (except at 300 and 600 ms where it was not significant) i.e. there was a higher amount of errors for compatible trials compared to incompatible trials. In the discussion, we will propose a potential logic for these findings.

In the dot experiment, the design was identical to that of the arrow experiment except that the arrow target was substituted with lateralized dot targets displayed to the left or right of the screen (i.e. not centrally). If the target dot was located at the right or left of the screen, the subject had to respond with the right or left hand, respectively. Yet, the results of the dot experiment differed significantly from those of the arrow experiment. In the dot experiment, at short SOAs, we found a PCE (which was however not statistically significant) i.e. there was a lower RT when the response hand (to the target dots) was on the matching side to the prime object's orientation. In contrast, we found an NCE at long SOAs i.e. there was a lower RT when the response hand (to the target dots) was on the reverse side to the prime object's orientation. In regards to the error rates, both the SOA/compatibility interaction and the main effect of compatibility were not significant. In the discussion, we will propose a potential logic for the findings of the dot experiment. In addition, we will propose ideas that can account for the different findings between the arrow and dot experiment. Note that in both the arrow and dot experiments, we used stimuli for which the hand used to grasp the object was unanimous in the first experiment.

V. REVIEW

1. Some general definitions

Here, we will start with some general definitions. When we mention the terms "illustration" or "representation" (which we will consider synonymous) we refer to the information stored in the mind [9]. When we mention "code" or "coding" we loosely refer to a means of representing information. Potentiation or priming loosely refer to processes whereby performance on a given task is improved or biased [10]. Motor simulation loosely implies that a subject is pretending to complete an action in his mind. When we refer to a motor programme, we refer to a series of actions that are planned to be done. Furthermore, note that in the thesis, we employ the term "treatment" as synonymous with "processing".

2. The basics on what happens between vision and action: introducing affordances

A complicated set of transformations from the visual to the motor system are necessary for the reach and grasp of an item (similarly to several other actions) [11]. There has to be a transformation of the trend of retinal stimulation into a sequence of muscle orders that give way to a correct grasp [11]. One might consider this mechanism to be a joining of two completely different stages: 1) the creation of a visual illustration of the item that is inside the surroundings and 2) the transfer of this visual data to the motor system, subsequently to the choice to act [11]. Yet, this account has limitations [11]. The illustrations we create of the surroundings must be associated to our capacities in terms of behavior in order for vision to control our actions effectively [11]. The visual system has to influence the motor system but the motor system has to influence the visual system as well i.e. both mechanisms rely on one another [11, 12].

As in one of the views above, it was initially postulated that perception and motor response mechanisms act in distinct phases [8, 13, 14]. According to this account of perceptuo-motor interactions, the activation of these phases occurs in a rigorously consecutive sequence [8, 13, 14]. On the other hand, some accounts (employing behavioral and electrophysiological data) postulate that there is a stream of information from the sensory systems to the motor ones which implies that, even prior to the cessation of perceptual and stimulus analysis, sensory information can activate and have an effect on the mechanisms of the responses [8, 15-20]. These accounts involve what is called 'asynchronous'[8, 15, 16] or 'continuous' [8, 17, 18] flow of information [8]. Gibson’s (1979) ecological view involving perception and action had the key notion that the main role of vision is to offer data regarding the potential actions, or *affordances* [11, 12]. The concept of an affordance basically associates the abilities of the subject in terms of behaviour with the visual display of the surroundings [11]. For example, earlier studies have demonstrated that the performance of an action occurring when a manipulable item is displayed is influenced by the correspondence of the action to the item [5, 7, 11, 21, 22, 23, 24].

Affordances involve the inclusion of the motor system in the item’s illustration that is visually generated [5, 11, 21]. In other words, in order for behavior to be co-ordinated and successful, the perception and evaluation of the potential actions afforded by items in the surroundings is necessary [25]. One item could lead to the affordance of a full array of options in terms of behavior (i.e. there are an endless amount of potential actions that can be performed in regards to even one individual item) [21, 5]. Affordances of items in terms of vision sustain or call for specific kinds of actions [25]. For example, the display of a handle can lead to the affordance for grasping the handle [25]. Conventionally, Gibson postulates that the concept of affordances for action is associated with the view of “direct” perception [12, 25]. In other words, the concept of affordances involves the fact that the opportunities in terms of behavior are afforded to individuals by items and surfaces and this information is recognised in a direct manner that does not require intermediate mechanisms [1, 12]. Indeed, Gibson postulates that affordances for action are founded on intrinsic features of items in terms of perception, registered in a direct manner that does not require intermediate mechanisms like item recognition [12, 25].

According to the affordance view, properties of an item (which can affect the manner in which the hand could interact with the item) like its location, size, shape, the position of the opposition space and orientation will cause activation of particular components of a reach and grasp action (a common action tendency which is substantially influenced by visual information)

[1, 5, 21, 26]. For instance, Tucker and Ellis (1998) (described later) demonstrated an orientation effect i.e. RTs were shorter for a keypress response where there was compatibility between the response hand (right or left) and the item's handle orientation [1, 5, 27]. As another example, some authors demonstrated a size effect [1, 7, 11] i.e. bigger items potentiate power grasps (i.e. grasping an item with the entire hand) and smaller items potentiate precision grasps (i.e. grasping the item with the thumb and index finger) [11, 27].

Also, a lot of research propose that simply observing items that are commonly employed in particular manners generates in an automatic way motor simulation for employing them [28]. In other words, many studies support the notion that a displayed item leads to a partial activation of motor illustrations linked to item-related actions [29-32, 11, 26]. That is, behavioral studies demonstrate that action tendencies of items (i.e. item affordances) can generate in an automatic manner the motor activation that is compatible with these item affordances [33]. In turn, many studies show that there can be a behavioral impact caused by this motor activation generated by the affordances of items [29, 33].

The congruency between an action and a displayed item's affordance can influence the performance of the action [21, 29, 22, 23]. For instance, items can lead to the activation of a specific response congruent with the item's orientation [29]. For example, Tucker and Ellis (1998) showed that RTs to execute orientation decisions (such as whether an object is upright or inverted) regarding an image of a tool is shorter when its handle is oriented in the direction of the response hand compared to the case where it is oriented in the opposite direction to the response hand [5, 28]. This result proposes that the orientation of a tool generates an action schema for grasping the tool with the nearest hand [5, 28]. Several authors have shown that the orientation (to the left or to the right) of items to be classified influences the execution of the task (i.e. the classification) with the left and right hands [5, 25, 29, 34, 35]. In such research, the performance was quicker with the hand congruent with the item's orientation regardless of the fact that the orientation is not pertinent to the task [5, 25, 29, 34, 35]. For several familiar graspable items like kitchen utensils or tools, the handle direction establishes the orientation of these items [26]. As another example, in one behavioral study, the subject observed an item with a handle oriented in the direction of the left or right hand and is instructed to respond by employing the left or right hand in terms of a certain feature of the target displayed on top of the item [1, 25, 33]. There is a facilitation effect for responses executed when there is compatibility between the hand and the item's orientation despite the item as a whole not being pertinent to the behavioral task [33].

Therefore, given that the motor plans are part of the item illustration, studies have demonstrated that an observed item's handle affordance leads to the automatic activation of a motor illustration of a specific hand compatible with the item's handle affordance [5, 33, 34, 35, 26]. However, selecting the hand employed to reach for an item is solely a single individual feature of a mechanism that leads to the actual grasp of an item [5].

3. What is a stimulus-response compatibility effect (SRC effect)?

The relationship between systems for perception and the systems for quick action is typically examined by employing experiments of stimulus–response (S–R) compatibility [25]. In the most trivial circumstance, such an effect implies a benefit in task execution when a feature of the stimulus and a feature of the response correspond [21]. SRC is indicative of the relative benefit of some mappings between stimulus and response compared to different mappings [5, 36]. The term "mapping" here implies the assignment of one type of response to one type of target (i.e. stimulus feature) and another type of response to another type of target (i.e. the opposing stimulus feature) [25, 37]. Some authors found that mappings which match the features that the stimulus and response have in common have shorter RTs compared to mappings that do not match these features [5, 36]. A trivial example of this is that allocating left and right responses to left and right items respectively, gives way to briefer RTs compared to the opposite mapping (i.e. allocating left and right responses to right and left items respectively) [5, 36]. Here, the stimuli (i.e. items) and responses both have in common the location parameter which makes the response easier when there is a congruent mapping rule [5, 36]. In other words, when subjects determine if a stimulus is displayed on the left or right (where location is relative), RTs and error rates are smaller when left or right displays are designated by the left or right hand, respectively in contrast to the opposite mapping [21]. In any situation where features of the stimulus and the sets of response are linked, the circumstances exist for finding SRC effects [5]. In other words, in the most basic situation, when there is a correspondence between a feature of the stimulus and a feature of the response, there is an advantage for task execution [21, 36, 38].

Many SRC experiments show that executed actions compatible (as opposed to incompatible) with the visual features of an item stimulus have smaller RTs and error rates [25, 39, 37]. Particularly, SRC effects can be found although the association is between a response and a feature of the stimuli which is completely not pertinent to the task [21, 38]. Also, studies regarding SRC back up the account that some action-linked features of an item (such as information involving location in space) produce response codes that are automatic [5]. For the purposes of the thesis, the PCE and NCE (described in the introduction) can be thought of as positive and negative SRC effects, respectively. However, note that when investigators simply mention an SRC (such as the SRC described in this paragraph), it implies a positive SRC.

4. Defining the theory of embodied cognition (the TEC account)

The following paragraphs go over the TEC account which is tightly linked to what has been described so far in terms of affordances. Some authors showed that the display of items can prime the generation of actions linked with the handle (like the display of a vertical beer mug primes a vertical power grip), which proposes that the display of items establishes in an automatic manner the action afforded by the item [27, 40, 41]. The theory of embodied cognition (TEC) serves to explain such 'action potentiation' effects [27, 42]. The TEC implies that there is a close connection, binding and integration between vision (or perception) and action early in sensory pathways which leads to visual-item illustration and affects performance [2, 43-48]. In fact, the TEC and the visual affordance account imply that the visual system offers direct information in regards to the choices in behavior afforded by objects (i.e. the potential actions in a picture) [2, 12, 43, 49]. According to Matheson, the theories of embodied cognition support the idea that: 1) item illustrations are distributed throughout modality-specific cortices and 2) simulations throughout these illustrations affect the execution of cognitive tasks such as naming an item [42, 50, 27]. In other words, there is a robust link between sensory-motor simulations and the illustrations of items in vision during cognitive tasks [50, 51]. Matheson explains that experiments involving 'action potentiation' lend support to the perception to action link [50].

In terms of the TEC, the presence of a potentiation effect supports the idea that the display of manipulable objects in vision automatically generates the sensory-motor simulations [50]. Indeed, Salmon explains that the TEC views support the idea that the manner in which we interact with our surroundings is implicated in the illustrations of items [43, 52-54]. Moreover, it is established that: 1) the visual display of an item leads to the activation of neurons in the motor system such as the 'canonical' neurons [27, 55] and 2) this kind of activation backs up the main notion of sensory-motor simulations throughout item illustrations [27, 50]. Yet, as will be addressed in this review, other authors do not entirely hold up the presence of the potentiation effect in terms of the TEC [50]. One such study by Anderson, Yamagishi and Karavia (2002) explains their results as an overall attentional bias to distinct components of asymmetrical items [50, 56].

5. Defining micro-affordances

The idea of micro-affordance stands in contrast to the idea of affordance that was initially pointed out by Gibson (1979) according to whom, features of the surroundings offer potential actions to the individual [12, 21]. According to the Gibsonian approach, these behavioral options are within the item i.e. they are completely specified by the trend of stimulation the item offers to the subject [21]. As opposed to this view of affordances as dispositional features of items and occurrences, the view by Ellis and Tucker (2000) (involving the concept of micro-affordance) considers the affordances to be dispositional features of a subject's nervous system [21]. The dispositions are generated due to the nervous system adjusting throughout evolution as well as a subject's life [21]. An additional distinction between Gibsonian affordance and the one established by Ellis and Tucker (2000) (micro- affordance) is related to the amount of specification [21]. The actions (which are made easier) demonstrated in the experiments of Ellis and Tucker (2000) involve precise components of grasping [21]. Also, they implicate specific values of the components involved being made easier (such as a power grip vs a precision grip in terms of the grip type component) [21]. In other words, it is not grasping in general being made easier, but rather a precise grasp attribute suitable to the observed item [21]. For instance, micro-affordances imply that observing an item will make the following features of actions easier: 1) specific reach directions (for the location attribute of the item), 2) specific shapes of the hand (for the shape attribute of the item grasp), 3) specific hands (for the orientation attribute of the item) and 4) specific wrist rotations [5, 21]. It is these primed features of a response involving grasping that are called micro-affordances [5, 21]. Indeed, some authors defined motor implications in item illustrations that are visually generated by the term "micro-affordance" with the goal of differentiating low-order action features like the shape of the hand, from the higher-order actions linked with the function of an item [11]. The connection between items and the actions normally performed with them is not limited to high-order actions like writing with a pen but can as well be observed at the microscopic level like the hand shape needed to grasp an item [5, 57, 58]. The term "visuomotor primitives" is tightly linked to this concept of micro-affordances and it implies, that with the lack of an ongoing intention, the type of motor illustrations evoked automatically by a visual item could be anticipated to stay somewhat simplistic (i.e. primitive) [11]. Such visuomotor primitives (like the features listed above in regards to micro-affordances) are alike for several distinct actions [11].

6. Defining the Simon effect

Here, we define the Simon effect since we will address it later. Studies disputing the affordance account involve the Simon effects which demonstrate that action is robustly regulated by object location [45, 59]: there are lower RTs and errors (task execution is easier) when the stimulus location (which is not pertinent to the task) matches the response hand (i.e. the response location) [45, 59-61, 38, 62]. Hence, this effect is accredited to stimulus location, not object grasping affordance [45, 59-61]. Stimulus location gives way to an automatic activation of the matching response-location code when the keypress responses are locations in space across an identical dimension [45, 60, 61]. For instance, when subjects execute responses with one of their two hands in terms of the colour or shape of an item, execution of the task is made easier if there is congruency between the location of the response hand and the relative location of the item display [21, 38, 25, 63, 64]. Several studies show that the results from micro-affordance effects (described in section 5 of the review) and Simon Effects act distinctly compared to each other [11, 25, 38, 62, 65, 66]. For example, experiment 3 of the Derbyshire study demonstrated the presence of a spatial Simon effect irrespective of the fact that the response hand/item orientation compatibility effects were absent [38, 62]. The Simon effect is the simplest example of an SRC effect [37, 38]. Interpretations of the Simon effect are founded on the idea of automatic abstract location codes [11, 38].

7. Direct item-action links

Research involving the execution of gestures in regards to items [67-69] do propose that there are direct associations between the depictions of items in terms of vision and the series of actions linked with their employment [11]. In other words, in circumstances where intentions are not stated, or not specifically stated, there must be a mechanism that allows the visual to motor transformations that have the highest pertinence, to have precedence probably founded on the previous history of how the subject interacts with visual items [11]. These direct item–action links could play a role in the production of motor trends that partly represent the affordance of an item [11]. Some neuropsychological [11, 67, 68] and behavioural [11, 69] studies regarding higher level item–action connections support the presence of a direct vision-to-action path without the need to involve semantic knowledge [11]. These direct item–action connections, created throughout the subject's life, allow the direct activation of higher level (functional) affordances by inputs in terms of vision in the absence of the intervention of semantic knowledge [11].However, Tucker and Ellis (2001) can not differentiate between the production of motor trends founded on the physical features of the item and those that have been established from the repeated link of an action with an item, founded on the function of the item [11]. These two origins (the physical features of the item and the item-action links) could offer information in standard conditions [11].

8. The integration between the visual and motor systems

The findings involving neurophysiological and neuropsychological studies support, in humans and monkeys, the presence of a specific vision-to-action path where there is strong integration between visual and motor illustrations, which leads to the creation of a visuomotor range which is challenging to separate into visual or motor treatment components (apart from the extremes) [11]. In other words, many studies support the fact that the transfer from visual to motor illustrations in the brain is not discrete, with significant cortical space contributing to sensorimotor integration [11, 70, 71]. Indeed, there is a tight association between visual and motor mechanisms which supports the idea of a continuum of visual to motor mechanisms [11, 72]. Across this continuum, there is no place where it can be correctly established that visual mechanisms stop and motor mechanisms start [11, 73] This integration is optimal for illustrating affordances and it renders achievable the activation of action features by visual items in an automatic manner [5, 11, 70, 71].

9. The role of our intentions or goals to act

Some authors employ the word "affordance" to indicate the motor trends whose illustration visual items and their features generate, in both: 1) overt intention-focused acts (see Jeannerod,1994, for an alike employment of affordances) and 2) prior to overt goals being made [5, 74]. The majority of physiological research of stimulus and response coding are completed with overt purpose-linked actions [5]. However, the set-up of the visual and motor apparatus offers a great amount of possibility for a partial illustration of visual and motor codes with the lack of a present goal to act [5]. In fact, when frontal cortical regulation is gone due to harm, "utilization behavior" can take place where visual items generate (in an automatic manner) motor responses like a reach and grasp action [5, 75]. This proposes that motor actions are regulated, to some extent, by the active inhibition and the following choice and tuning of associations between the sensory and motor systems that were present beforehand [5, 76]. Therefore, despite the fact that our instant intentions are relevant in establishing the visual information that is pertinent, and which affordances must be extracted to accomplish those intentions, it could also be assumed that the actions afforded by an item must be rendered accessible in a manner that does not rely on our intentions [11]. Indeed, the manner in which the specific features of a high-level intention are produced, rely somewhat on the individual's capacity to extract information regarding the potential actions in the surroundings, regardless of whether these potential actions could help give way to the wanted final state or not [11]. To effectively execute such an intention necessitates the capacity to produce illustrations of possible actions that the surroundings afford (see Gross, Heinze, Seiler, & Stephan, 1999, which describe a neural model that includes hypothetical actions as a resource for sensorimotor preparation) [11, 77]. However, a subject's ongoing purposes evidently offer significant restrictions on the visual information that is pertinent in accomplishing these purposes [11].

10. The importance of inhibition

Humans are constantly shown possible affordances in their normal surroundings which are generated by normal common items [26]. Yet, typically, the automatic activation of action illustrations generated by such affordances does not cause performance of the matching action in an involuntary manner [26]. In fact, the motor system has to make certain that there is an inhibition of the motor activations automatically generated by features of visual items like affordances which in turn could interfere with the ongoing intentions in terms of behavior [33]. In neuropsychological studies, patients with defective motor inhibition processes have a higher propensity to perform action schemas generated by affordances [26, 23, 75]. Experiments with patients suffering from anarchic or alien hand [25, 78], demonstrate that features of items in terms of vision in some cases generate related unwanted action or gesturing [25, 23]. One explanation of utilization behaviour, where patients with harm to the frontal cortex seem to lack the capacity to supress themselves from employing items positioned in their surroundings, is that the items generate compulsive actions that the patients lack the capacity to supress [25]. In other words, there is an automatic activation of reach-to-grasp movements generated by observed items despite the fact that these patients (with damage to the frontal lobe) are instructed to refrain from such movements toward the item [26, 75]. The findings in some studies support the view that processes that allow illustrations of motor programmes in regards to observed objects necessitate inhibition processes that make certain that the automatic generation of motor activation does not disturb the current behavior and cause undesirable actions [26, 23]. Such a disturbance can be caused by a defect in the patient regarding the processes involved in inhibiting the motor illustrations activated automatically by item affordances [29, 23]. Thus, an automatic behavioral impact can be caused by the handle affordance of displayed items [29]. Yet, in standard conditions, the visual stimuli do not generate in an automatic manner the actions linked with those stimuli except in cases of patients with impairments, like utilization behaviour [75], which can take place due to the defect in frontal inhibitory regulation [11]. Moreover, Ellis and Tucker (2000) mention that the effect of action priming by observed items (i.e. observed items making components of actions easier) are slight effects, since they should not interfere with the ongoing, intention-related actions [5, 21].

The inhibition linked with handle affordance is an essential process associated to motor planning mechanisms [26]. Disturbance of behavior can be generated by motor illustrations that are activated by a distractor item's orientation [29, 79]. Studies that assessed exogenous motor inhibition processes have focused on the manner in which affordance information of distractor items disrupts the response performance in regards to the target item [29, 79, 80]. As a whole, these studies show that the handle affordance of a displayed item leads to an automatic activation of motor illustrations of the hand that matches the orientation of the handle [29, 79, 26]. In turn, this makes matching responses easier [29, 79]. Yet, in subjects with a healthy motor system, if the handle affordance of a distractor item activates a motor illustration, this motor activation is inhibited in an automatic manner [29, 79]. These results fit with the model that implies that the system responsible for the preparation of an action can lead to the activation of action plans for several items at the same time [26, 81]. In turn, these action plans generated by distractors are inhibited automatically [26, 80, 82]. Furthermore, in other studies, in a negative priming task, when two items are displayed at the same time, the illustrations of disregarded items in terms of perception are inhibited in an active manner leading to a bias towards the processing of the target item [29, 83, 84]. Also, other authors have shown that, when the target is displayed with distractor items, motor illustrations as well as perceptual illustrations which are linked to items that are not pertinent to the task are inhibited [29]. This is necessary since, for instance, when subjects are told to reach for a target with a given colour in the presence of multiple other possible targets in the environment, the position of distractor items disrupts dimensions of the reach and grasp action in terms of: space (like the path of the reach) and time (like the time of the reach) [29, 85]. Other studies observed that apart from the position of the distractor, its size can also disturb behavior [29, 80]. Another study employed a new motor inhibition methodology which showed that an alike motor inhibition impact formerly related with distractor items presented at the same time as the target object can also be seen when the motor activation is generated by a short presentation of an item that is task-irrelevant [29, 37]. In another study, the task involved reaching for an item (which had a handle in the direction of the left or right hand) and this item disappears at the start of the reach response [26, 86]. When there is compatibility between the hand of response and the item's orientation, the RT increased [26, 86]. These findings support the notion that if a sensory backing that updates the initial response activation disappears in the midst of task performance, there is an instant inhibition of the initial motor schema [26, 86].

11. Endogenous and exogenous inhibition

Endogenous inhibition is an inhibition that is voluntary, volitional, optional and is seen when cues pertinent to the task are available to conscious perception [8, 87, 88]. Exogenous inhibition is an inhibition that is reflexive (automatic), involuntary and does not rely on cues pertinent to the task being available to conscious perception. [8]. The display of stimuli close to or under the verge of conscious awareness can lead to mechanisms involving subliminal activation of motor responses [8, 89-92]. Hence, the lack of conscious perception can still permit information in terms of perception to influence the motor system [8, 89-92]. Thus, perceptuo-motor connections occur in a direct manner [8, 89]. The advantage of such connections is that they permit us to react to fast alterations in the surroundings, rapidly and agreeably [8]. Yet, stimuli that are not consciously perceived or are not interpreted entirely can lead to motor responses being activated which can hinder performances that are in progress or lead to unwanted behavior [8]. In other words, given that an observed item activates motor illustrations automatically, the motor system requires some processes to deal with the activation of motor illustrations that are generated by objects that are not pertinent to behavior [29, 93, 94]. Eimer focuses on the activation of inhibitory mechanisms toward responses generated by subliminal stimuli, thus, avoiding unwanted outcomes in terms of the continuous perceptuo-motor stream of information [8].

According to several authors (using behavioral and electrophysiological means), the inhibition of responses in general has an important function in regulating motor processes [8, 95-101]. For example, some authors have used stop-signal or go/no-go tasks (where subjects have to avoid making a response when a particular signal is displayed which leads to the inhibition of the response once the subject identifies the stop or no-go signal). Such tasks examine processes that inhibit undesirable motor responses [29, 96, 100] and have led to the assumption that there is "endogenous" inhibition which is intentional, non-obligatory and under cognitive regulation [8, 87]. In turn, endogenous inhibition requires conscious awareness of cues that are pertinent to the given task [8]. Thus, there is no endogenous inhibition for subliminal stimuli [8]. Indeed, according to many studies, subliminal stimuli are not affected by endogenous inhibition which only plays a role on supraliminal stimuli that are consciously perceived [8, 83, 87, 102-105]. However, subliminal stimuli still give way to passive activation processes which are automatic [8, 83, 87, 102-105]. On the other hand, supraliminal stimuli are necessary for active inhibition to occur [8].

Other methodologies served to examine how exogenous (involuntary) inhibition processes obstruct response activations that could interfere with the present intentions in terms of behavior [29, 106]. In fact, the masked-priming paradigm (described later) is typically used to examine how inhibitory processes that take place exogenously (involuntarily) inhibit response activations that are likely to interfere with the ongoing intentions in terms of behavior [33, 107]. Once again, according to Eimer (i.e. the masked-priming paradigm), inhibition mechanisms can be seen with prime stimuli that are masked and not consciously perceived [8]. Also, subliminal masked primes drive an early response activation prior to the prime-linked inhibition [8]. As opposed to endogenous inhibition (for supraliminal signals that are pertinent to the response), exogenous inhibition involves subliminal primes that lead to an early response activation which directly causes response inhibition [8]. Hence, not all inhibitory mechanisms are endogenous: exogenous inhibition occurs by reflex even when the stimuli are unconscious [8]. Moreover, the model proposed by Eimer in regards to subliminal priming does not postulate high order or cognitive mechanisms to control the inhibition of the response [8]. When a specific association between stimulus and response occurred, the activation and inhibition mechanisms take place automatically and are generated in an exogenous way by features of the masked prime in terms of perception [8].

Furthermore, endogenous and exogenous inhibition are mediated by mostly distinct neural substrates i.e. the mechanisms involved in the regulation of responses tendencies caused by subliminal data differ from those caused by endogenous executive regulation processes [8, 87, 108, 109]. Regardless of these distinctions between exogenous and endogenous inhibition, both processes influence motor regulation and can be present in parallel [8]. In fact, in cases where stimuli that are not pertinent to the response are displayed supraliminally but where the repression of a motor tendency generated by these stimuli is not likely to be a voluntary judgment, the two kinds of inhibition influence the regulation of inappropriate response tendencies [8]. In fact, some authors do not rule out that exogenous and endogenous inhibition could be founded on principles which are not completely distinct [8, 110]. Also, they state that endogenous and exogenous inhibition do not in all cases function independently and in a completely distinct manner [8].

12. The masked prime paradigm

Many earlier studies have shown that the response to a target stimulus in vision can be affected by the preceding display of a visual prime stimulus even though the prime was imperceptible due to a following mask [92, 111-118]. The main purpose of Eimer's review (which involves the masked prime paradigm) is to demonstrate (through behavioural, electrophysiological and functional imaging research) that it is not only conscious stimuli that are affected by inhibitory regulation and masked primes can lead to response activation (i.e. cause their corresponding response) followed by inhibition if the strength of the early activation is above the inhibition threshold [8]. In fact, a lot of earlier research demonstrated that behavior can be influenced by subliminal stimuli [107, 119]. Hence, when response activations are caused by unconscious subliminal stimuli, inhibition mechanisms can still regulate response tendencies (i.e. they are still active) [8]. This "exogenous" inhibition seems to occur by reflex and does not require the conscious identification of cues that are task-pertinent [8]. The authors used a masked prime methodology to examine the effect of subliminal stimuli on the mechanisms related to the response [8, 107]. In this methodology, a prime stimulus is displayed for a short period of time (16 ms), prior to a mask (100 ms) and a target stimulus (100 ms) that involves a selection response [8, 107]. The important factor involves the association on a given trial between the prime and the target: 1) when both correspond to an identical response (compatible trial), 2) to the reverse response (incompatible trial) and 3) do not correspond to any response (neutral trial) [8, 107]. Double arrows are used as both primes and targets and a compatible trial implies that the arrows of both the prime and target point in the same direction. When double arrows in the target point to the left or right, they correspond with a response with the left or right hand, respectively [8, 107]. The behavioral results were opposite to what was expected: there was a better task execution for incompatible trials compared to compatible trials [8]. Hence, compared to neutral trials, the RTs and error rates were less for incompatible trials and greater for compatible trials i.e. compatible trials involved costs in terms of task execution while the incompatible trials involved advantages in terms of task execution [8]. This is called the "negative compatibility effect” [8]. This effect is considered to be a strong effect of subliminal priming since it has been found in many studies [8, 120-126]. Therefore, the slight modification to the target priming paradigm of adding a mask could reverse the priming effect leading to shorter RTs on incongruent trials compared to congruent trials [107, 111, 120, 121, 123, 124, 126, 127]. Given that negative compatibility effects do not come from processing at perceptual or central semantic levels (as described in sections 63 and 45 of the review, respectively), the alternative is that they are produced inside the motor system [8]. Studies involving subliminal priming with the lateralized readiness potential (LRP) offer the strongest support for the impact of masked primes on motor mechanisms [8, 107]. One can refer to the Goslin, Lien and other studies for a definition of LRPs and ERPs (including the P1 and N1 components) and what these measures indicate [2, 44, 6, 8, 97, 128-132]. Eimer and Schlaghecken (1998) (the method is described above) assessed the LRPs [8, 107]. The results depicted an early activation of the response related to the prime (i.e. the prime arrow generates a partial activation of responses compatible with the arrow) at 200ms following the start of the prime [8, 107]. In turn, approximately 300 ms following the start of the prime, there was a reversal of the early effects (in polarity) [8, 107]. This reversal is viewed as a successive inhibition of the early activation (i.e. there is a reversal in the response activation which is indicative of inhibition of the earlier response inclination) [8, 33, 107]. Hence, these response inclinations are supressed by self-inhibition processes if facilitatory inputs such as visual sources are not supporting an adequate amount of activation [8, 33]. Eimer assessed these results as a trend of primed response activation prior to response inhibition [8, 107]. At first, the continuous stream of data between the sensory and motor phases leads to the activation of the response related to the prime. Hence, sensory data can quickly modulate response mechanisms [8, 107]. The pattern observed in the LRP displays that if the response to the target is chosen during the stage of inhibition (300 to 400 ms after the start of the prime or 200 to 300 ms after the start of the target), this would clarify the NCEs of the behavioral results [8]. In other words, in this time window, there is an inhibition of the response corresponding to the prime i.e. smaller RTs in incompatible trials than in compatible trials [8]. Hence, the inhibition could take place because the appearance of the mask efficiently eliminates a sensory backing for updating the earlier response activation [8, 33]. The NPE can be seen when response choice occurs in the inhibitory stage and it is indicative of inhibition mechanisms of the visuomotor system (not perceptual mechanisms) [8, 33, 133].

13. The masked prime paradigm: temporal features

Several studies support that a short presentation of prime items can be linked with motor inhibition [29, 37, 107]. The masked-priming paradigm (a common NCE paradigm) also displayed alike NCEs which are inferred to be a confirmation of this inhibition [8, 29, 107]. This paragraph goes over studies by Eimer & Schlaghecken that employed the masked-priming paradigm [8]. The masked primes at first drove a response tendency that was, afterwards, inhibited [8]. Indeed, the LRP waveforms lead to the account that there is a biphasic pattern of activation before inhibition [8]. Hence, Eimer tried to find behavioral data supporting the early response activation by modulating the time interval or stimulus onset asynchrony (SOA) between prime and target [8, 121]. In other words, Eimer tried to assess the choice of a response to the target at some point in the activation phase which occurs early on [8, 121]. The masks and targets are displayed at the same time for the 0 ms SOA and the SOA between the mask and target rose by stages of 32 ms for the remaining SOAs [8, 121]. In such a paradigm, subjects perform a keypress response with the right or left hand to a target arrow pointing to the right or the left [8, 29]. The arrow follows a backward masked prime arrow (shown for a short amount of time of 16 ms) [8, 29, 33]. Since masking decreases prime visibility (which becomes subliminal), subjects typically can’t consciously observe the primes (which is shown in the prime identification task involving forced-choice being at or close to chance level) [107, 134-136]. Subjects have a shorter RT and lower error rate in compatible trials when the target is displayed instantly following the masked prime with an ISI (i.e. SOA) of 0 to about 60ms i.e. short SOAs [8, 29, 107]. This represents a PCE i.e. for compatible trials, there are advantages in terms of behavior compared to neutral trials where as for incompatible trials, there are costs compared to neutral trials [8, 29, 107, 134-136]. This occurs since response choice occurs during the early activation stage [8, 121]. Yet, when the time between prime and target rises (greater than 60 ms or approximately 100 to 150 ms), there is a benefit for incompatible trials (compared to compatible trials) in terms of behaviour i.e. the target responses have measurable benefits (like short RTs and lower error rates) when the target follows an incompatible prime (which cues the reverse response compared to the target) where as the target responses are deferred when the target follows a compatible prime (which cues an identical response compared to the target) [8, 29, 33, 107, 119, 121, 134]. This NCE occurs since response choice occurs during the later inhibition phase [8, 121]. This represents an NCE which demonstrates self-inhibitory processes of the motor system [8, 29]. Such a process makes sure that a primed undesirable response activation leads to the motor activation being replaced by an inhibitory phase instantly, automatically and inevitably [26, 110, 137]. Similar to these findings, several studies involving the inverse priming paradigm, demonstrated that inverse priming effects rely strongly on: 1) a detached mask being used and 2) an SOA for the delay between the display of the mask and the subsequent target that is long enough (around 150 ms) [111, 120, 126, 127, 138-140]. The NCE can be explained by the fact that the prime generates a motor activation followed by the mask which eliminates the sensory backing necessary to update the earlier response activation leading to the inhibition [26, 141]. In other words, the inhibition takes place due to the fact that the start of the masking stimulus eliminates the sensory backing that updates the early response activation [8, 29]. The stimuli that are "near-threshold" generate an incomplete motor activation that is processed by the motor system as an undesirable activation since it could ultimately lead to an undesirable explicit behavior [8, 29]. Hence, the inhibition of this response activation occurs right away [8, 29]. When the response choice occurs in the inhibitory stage, one can find an NCE [8, 29]. In contrast, if the stimulus is presented for a long amount of time such that it becomes supraliminal, it leads to a PCE [8, 29]. It does so due to the fact that it generates a motor activation that rises above the hypothetical threshold needed to get a PCE [8, 29]. When the motor activation rises above the threshold, inhibitory processes stop inhibiting the activation efficiently and do not lead to NCEs [8, 29]. Indeed, the LRP waveforms lead to the account that there is a biphasic pattern of activation (i.e. PCEs at short SOAs) before inhibition (i.e. an NCE at long SOAs) [8, 121]. Based on the above studies, the behavioral priming effects are directly indicative of the temporal features of response activation and inhibition in terms of LRPs [8, 120].

14. How the central-peripheral asymmetry leads to the "inhibition threshold hypothesis"

When masked primes are in all cases displayed at fixation, the short SOA between prime and target led to PCEs which became NCEs for longer SOAs which is indicative of a series of effects that represent self-inhibitory regulation circuits [8]. In opposition to primes displayed in the center (as in previous experiments), no NCEs were found for peripheral primes i.e. the PCE (RTs were smaller for compatible compared to incompatible trials) was seen not only for short SOAs but also stayed for the entire array of SOAs in their study [8, 121]. The peripheral prime condition also altered the LRP: 1) for central primes at short SOAs, only a partial response activation was seen and there was a lack of a later response inhibition, 2) for central primes at long SOAs, both the early response activation and the later inhibition phase were seen, 3) for peripheral primes, solely the early response activation stage was visible and became more prominent as the SOAs rose [8, 121]. Hence, as opposed to the central prime, there was an absence of inhibition even when SOAs became longer [8, 121]. In other words, both the behavioral and LRP findings postulate that there is an early response activation for both central and peripheral primes but that activation is only followed by inhibition for central primes with long SOAs but not for peripheral primes although SOAs are just as long [8]. Yet, Eimer does not disclaim that an NCE and inhibition can be seen for peripheral primes for SOAs that are much larger [8]. Since Eimer established that spatial attention does not play a role in this 'central-peripheral asymmetry', another experiment pointed out an alternative explanation where this asymmetry is caused by modulations of sensitivity in terms of perception [8, 121]. In the experiment by Schlaghecken and Eimer, there was an ongoing alteration of eccentricity of masked primes when they were displaced in the surroundings from the fovea to the periphery leading the NCE to be reduced and to ultimately become a PCE [8, 121]. In other words, the change in compatibility effects occurred together with the reduction of sensitivity in terms of perception from the central retina to the peripheral retina [8, 142]. Hence, 'central-peripheral asymmetry' is associated with the sensitivity in the retina and in turn with modulations of the strength of sensory traces caused by primes [8]. An increase or decrease in the strength of response activation is correlated with a similar increase or decrease in that of the sensory illustrations of the primes [8]. Hence, motor tendencies are stronger when generated by foveal compared to peripheral primes [8]. The fact that they can observe an inhibition for central primes but not for peripheral primes leads to the assumption that there is an inhibition threshold [8, 123]. The rationale is that the probability for weak prime-generated motor response activations (such as those caused by peripheral primes or perceptually weak stimuli) to affect continuing explicit behavior is smaller and more unlikely leading these weak prime-generated activations, which are under the inhibition threshold, to go away after a while in a passive manner [8]. Hence, we can only observe response facilitation but not the following inhibition [8]. In contrast, only strong prime-generated motor activations (such as those caused by foveal primes) might influence explicit behaviour (even for unconscious awareness of the stimuli) and need to be inhibited in an active manner [8]. Thus, the role of the inhibition threshold is to cause inhibition for response tendencies that are sufficiently strong to affect explicit behaviour [8]. In turn, the inhibition threshold still permits the mechanisms linked to the responses to be influenced by the ongoing stream of information from sensation [8]. By modulating the perceptual strength of foveal and peripheral primes, Eimer assessed the 'inhibition threshold' hypothesis [8, 123]. They show that enhancing the perceptual strength of peripheral primes (by for example increasing the interstimulus interval between primes and following masks) transforms PCEs and the absence of inhibition (caused by an activation that is under the threshold) into NCEs and the presence of inhibition [8, 123]. In turn, reducing the perceptual strength of foveal central primes (by for example overlapping the primes with random dot degradation fields) transforms NCEs and the presence of inhibition (due to response activations that are superior to the threshold) into PCEs and the absence of inhibition [8, 123]. These results fit with the inhibition threshold hypothesis: inhibition caused by masked primes correlates with the perceptual strength of those primes [8]. Thus, response activation prior to inhibition is caused by strong perceptual traces and the response activation stays under the inhibition threshold with weaker perceptual traces [8]. To sum up, the prime must generate a motor activation that surpasses a hypothetical inhibition threshold in order to find an NPE [33].

15. Self-inhibition

The self-inhibition processes of the motor system that assess the response activation generated by prime items (presented for a short amount of time) as an undesirable activation are thought to account for negative priming effects [8, 33]. Self inhibitory control circuits involve the trend of the biphasic pattern of facilitation prior to inhibition i.e. if you activate a unit, it leads in a direct manner to a consequent inhibition [8, 110, 137]. In fact, some authors suggested the self-inhibition model of the NCE where there is an automatic motor activation by a subliminal prime followed by the generation of an inhibition counter to the earlier activation [107, 119, 123, 134, 135, 174]. Indeed, some studies have shown that PCEs and NCEs are indicative of sequential stages of automatic activation and following self-inhibition mechanisms which is a typical property in low-level motor regulation [8, 107, 120, 121, 123, 134, 136, 144]. Hence, the self-inhibition mechanisms function to prevent the motor effects of the visual stimuli that are not visible (i.e. they are subliminal) but are the cause of motor activation which could interfere with the current behavior [33, 135]. Indeed, the display of a mask suddenly stops the early activation stage [134]. A successful mask eliminates the neural illustration of the prime [134]. In turn, the early primed response is not backed up anymore by matching sensory input [134]. This abrupt absence of support in terms of perception generates an active self-inhibition mechanism which functions as an emergency brake process to inhibit a response inclination that is outdated [134]. Moreover, the LRP findings in previous studies back up the motor self-inhibition model that explains the NCE in the masked-priming paradigm [26, 107, 131, 145]. If inhibition mechanisms linked with the prime correlate with self-inhibitory circuits and are controlled by self-inhibitory processes in motor regulation, inhibition should have the following characteristics: 1) instantaneous, 2) automatic 3) all response activations should inevitably lead to this inhibition [8]. The case of the peripheral primes described in the paragraphs above may be an exception to the latter characteristic due to the "inhibitory threshold hypothesis" [8]. In addition, in typical experimental circumstances, where the stimuli that are pertinent to the response are displayed in a supraliminal manner, task execution will not be influenced by self-inhibition [8]. In other words, when stimuli pertinent to the task are displayed in a supraliminal fashion, there is a lack of abrupt elimination of sensory support for a pre-activated response [8]. Thus, the existence of self-inhibition was potentially not observed in earlier research since motor regulation tasks typically used supraliminal stimuli [8]. Hence, they assume that particular experimental conditions like those of the masked priming paradigm are necessary to reveal the effect of self-inhibitory motor regulation circuits by removing the effects on response mechanisms of perceptual inputs that lead to facilitation [8]. To sum up, some authors state that this NCE (i.e. the self-inhibition model) [123, 134, 146] involves the following conditions: 1) prime items that are alike to target items lead to the activation of matching motor responses, 2) there is an automatic self-inhibition of this activation when the perceptual support for the prime disappears (i.e. the masks must instantly block the sensory support of the prime) [119, 135] and 3) self-inhibition takes place solely when the sensory strength of the prime is great enough to generate this inhibitory process (the "inhibitory threshold hypothesis") [119, 135, 146]. According to some authors, without these circumstances, a PCE would be anticipated [146].

16. Addressing the task-relevancy of employed stimuli

Some neuropsychological studies show that some item features (like the handle orientation) influence responses to the greatest extent when those features are more pertinent to the task [11, 23]. However, the critical finding of Tucker and Ellis (2001) is that their demonstrated compatibility effects were founded on properties of the experimental stimuli that are task-irrelevant [11]. In fact, Ellis and Tucker (2000) demonstrate that the participants are influenced by grasp-associated features of an item that they have no intention of grasping and there exists many studies supporting the fact that, in a given task, responses are made easier by features of a visual item that are not pertinent to the task [21]. For example, in the Simon task, the position of a target item can affect how fast the responses based on space are, although this position of the target is task-irrelevant [11, 38]. In fact, Ellis and Tucker (2000) assume that additional action-linked properties, like size, shape and orientation, probably have alike effects to the location property (such as that of the Simon effect) where location is an attribute of the visual item that prompts action-linked response features regardless of the subject's objective [21]. Tucker and Ellis (1998) also examined this notion [5, 21]. Furthermore, both experiments of the Ellis and Tucker (2000) study support the view that at least some compatibility effects are related to the micro-affordances that every item generates irrespective of the subject's purpose [21]. Indeed, they assessed the effects of observed items on a response executed in regards to a completely distinct, sound, stimulus [21]. Moreover, all three experiments of the Phillips and Wards study evidently demonstrate that visual affordances of items can potentiate action, despite these items and affordances being non-pertinent to the ongoing purposes of the task [25]. Also, the impact of a non-pertinent prime on responses (which was shown in Phillips and Ward (2002) where target form established the response) can also be found in Vainio (2007) (described in section 29 of review) despite the fact that the target colour establishes the response [1, 25]. Furthermore, in regards to Vainio and Mustonen (described in section 28.1 and section 28.2 of review), there is a facilitation of manual responses by the static picture of an observed hand prime whose identity is compatible with the response hand despite the fact that the task involves a response to a stimulus property that does not require the hand identity to be retrieved [37]. This supports the idea that retrieving an observed hand's identity and mapping it to the matching motor system of the left or right hands occurs automatically i.e. it doesn't rely on an obvious goal to assess its identity [37].

17. Introducing the dorsal system and ventral system

Early visual data is divided into ventral and dorsal visual cortical processing streams depending on the kind of data that is being processed [52, 147-150, 151]. The ventral pathway is linked with item recognition and identification or the discrimination of patterns where as the dorsal pathway is linked to the treatment of spatial features of items like spatial location and navigation [11, 21, 152]. Also, some neuropsychological studies have demonstrated that every facet of visuomotor activity involves the dorsal pathway [5, 153, 151, 148, 154]. Some findings propose that the dorsal pathway is related to the regulation (or illustration) of item-linked actions [21, 153, 151, 148]. Thus, the difference in terms of function between the ventral and dorsal pathway was reassessed [11, 151, 148, 154] as a difference between: 1) perceiving the environment for identification and experience and 2) the employment of vision for every facet of visually-controlled action [11].

The dorsal system is thought to be the network involved in the conversion of data in terms of vision into a motor output with very little impact from other systems such as the ventral system [7, 153, 151]. Indeed, the dorsal system seems to be an appropriate contender for producing visuomotor illustrations founded only on the physical features of items [11]. However, the ventral system may (through a 'steering role') allocate the dorsal system to an appropriate target [7, 155] after which, the features of the target item are converted to motor output automatically with very little impact from the ventral system [7]. In other words, the dorsal system is not secluded and could be affected by additional inputs (comprising inputs from the ventral system) so that the appropriate visual to motor transformations occur [11]. The specific role of the dorsal system is the on-line modulation of an ongoing action [7, 156]. The assessment of an item's features to allocate an action must be calculated rapidly and accurately [7]. It is required that object features which rely on the vantage point (like location and orientation) must be examined on-line since this data can be altered uninterruptedly during the movement of the observer or that of the target [7]. However, a subject still keeps in mind some spatial data off-line i.e. one can reach for objects or move around them using memory even though they would do so inaccurately and carefully [7].

18. Distinguishing extrinsic and intrinsic item features

One can classify item features as extrinsic or intrinsic [62]. Intrinsic features (such as grip type) do not vary and unavoidably take place together with the display of an observed item [62]. Extrinsic features may vary and rely on an association with the subject or the settings in which it is observed [62]. As an example of extrinsic features, there may be various distinct orientations while observing items and knowledge regarding its specific orientation only takes place when the item is observed or well depicted and the subject's position in regards to the item is considered [62]. The kind of grip (i.e. precision vs power grip) afforded by an item is independent of the location and distance where as more momentary affordances, like the orientation of a reach action, do depend on these factors [11, 157, 74].

19. Addressing the quick decay of the effect after the offset of the item

The results of Tucker and Ellis (2001) fit with the notions the authors demonstrated in other studies [5, 21] that the visual illustration of items involves the partial activation of the motor trends linked with their affordances [11]. The fact that this activation decreases quite rapidly after the offset of the item backs up the concept that it is the product of the quickly updated visuomotor mechanisms linked with the dorsal visual system [11]. That is to say, one feature of visuomotor mechanisms in the dorsal pathways is that it generates somewhat temporary illustrations (by being quickly updated) of item features that are pertinent to action [11, 155, 158]. This is a necessity of any system built to offer helpful information for regulating actions [11]. In other words, according to Tucker and Ellis (2001), the on-line or dorsal route for retrieving affordances (which depends on on-line calculations that are brief and quickly updated) goes together with the quick decay of the effects after the disappearance of the item [7, 11]. They postulate that the offset of the item leads to the end of the visual-motor conversions that drive the activation of the compatible or incompatible motor response [7]. Indeed, they infer that their compatibility effects are generated by the on-line dorsal system [7]. Also, in previous experiments by Tucker and Ellis (2001), it was postulated that the quick decline of the affordance effects after the disappearance of the visual item made sense with the fact that the activation of the motor trend occurred by the dorsal route [7, 11].

As will be further addressed later, neuropsychological studies have demonstrated a difference between visual information employed for item recognition and for action i.e. patients can have intact visually controlled action but a defect in item recognition [159, 160]. This advantage in terms of visually controlled action (compared to item recognition) is eliminated when a time interval is put in place between stimulus display and the following action [159, 161]. This quick decay of activation goes along with the notion that a direct visual path to action (described later) is critical for the online choice and control of action [159]. Yet, previous experiments could not definitely preclude other accounts [7]. In fact, the purpose of the experiments by Tucker (2004) was to assess once more the affordance-based grasp effects with time-course situations that would allow or preclude the accessibility to an on-line visual item in the process of response selection and performance [7]. Their results contradict those of Tucker and Ellis (2001) explained above: the generation of affordance compatibility effects does not require the presence of the visual item at the moment where response choice is executed [7, 11]. In the Tucker (2004) study, their three experiments (involving grip type) preclude the involvement of the on-line element of the dorsal action stream i.e. an active item illustration is enough to produce affordance compatibility effects based on related actions to the items regardless of whether the item is simultaneously visible [7].

20. A summary of the Goslin and Lien studies

In the Goslin study, subjects must categorize items as kitchen utensils or tools by making a keypress response with the left or right hand [2]. The handles of these common items are oriented either to the right or the left [2]. The first experiment in the study by Lien replicates this Goslin experiment (i.e. the item is positioned at the center of the screen) [2, 44]. The second experiment by Lien is mostly similar to their first experiment but the objects are displayed either in the center or in the periphery [44]. In their third experiment, the item is displayed centrally but there are two different conditions: 1) object-centred and 2) base-centred [44]. The former condition is the same as the display in Lien's first experiment as well as the central display of the item in their second experiment and in the Goslin study (apart from color and size) [2, 44, 162]. In this object- centered condition, the entire item is presented in the center and the handles are placed in the median line [2, 44, 162]. Hence, the position of the handle is not evidently to the left or right of the screen [44, 162]. In the latter condition (base-centred), only the base of the item is positioned in the centre such that the position of the handle is clearly to the left or right side of the screen [44, 162].

Goslin (which assessed the object-centred condition) concluded that there is a correspondence effect (i.e. congruency effect) between response hand and the orientation of item handles in RT, P1 and N1 as well as the stimulus-locked LRP [2, 44, 129-131]. In turn, they support an affordance effect [2].

21. Lien supports the spatial-coding account (not the affordance account)

21.1 Lien's second experiment used two conditions: 1) the central location condition where the object is shown at the center of the display and 2) the peripheral location condition where the object is shown either on the left or the right side of the display [44]. Lien hypothesized that the grasping affordance account [5, 163, 164] would lead to correspondence effects in both conditions while the spatial-coding account (due to location coding) [162, 165-168] would lead to correspondence effects only in the peripheral condition [44]. Regarding both the RT and PE, this correspondence effect was greater for peripheral items (which were significant) compared to central ones (which were nonsignificant) [44]. In other words, for central items, as in the results of their first experiment (which also used central items), there was a lack of correspondence effect in terms of RTs [44]. Yet, peripheral items generated a big correspondence effect in terms of RTs which was alike in size to the common Simon effect (defined prior in section 6) [44, 162, 166].

21.2 Lien's third experiment uses a similar method to Cho and Proctor [44, 162] i.e. they employed solely the central condition which was displayed in 2 different manners : 1) the object-centered condition and 2) the base-centered condition (both described prior in section 20) [44, 162]. The hypothesis is that, if there are the same correspondence effects in both conditions, the affordance is the cause of these effects leading to the validation of the affordance view [44, 162]. Lien found a high significant correspondence effect for RT and PE only in the base-centered condition which supports the spatial-coding view [44, 162]. Thus, they did not find the object-centered condition to lead to a correspondence effect since it lacks a spatial code [44, 162].

21.3 Also, when Lien pool the results for the condition where items are displayed in the center of the screen in all three of their experiments, the correspondence effect in terms of RTs as well as P1 and N1 was small and insignificant (and there was a lack of significant correspondence/category interaction) [44]. Therefore, the behavioral results in terms of central objects and peripheral objects do not lead to the conclusion that there is a grasping affordance view where the orientation of the item and not its location would strongly establish the presence or absence of the object-based correspondence effect [44]. This opposes Goslin's conclusion even though Lien has a greater sample size and number of trials compared to Goslin [2, 44]. Hence, their findings back up the spatial-coding view: the location of the item will strongly establish the presence or absence of an object-based correspondence effect [44]. Thus, according to Lien, the distribution of visual/spatial attention is controlled by object location (not handle orientation) [44]. Yet, it can not be precluded that there could be a combined object-based correspondence effect of the grasping affordance view and the spatial coding view which would give way to peripheral objects having even greater correspondence effects [2, 44, 45, 162].

22. The importance of decisions that involve attributes linked to affordances

In an object-centred condition, Tipper found a correspondence effect evoked by the grasping feature of the stimuli for shape decisions (not color decisions), with only the former decisions comprising attributes linked to affordances and being altered by the extent to which an item affords a specific action [35, 45]. Thus, correspondence effects were due to action affordance generated by the items (not due to the low-level visual characteristics like color) and the item's orientation (not its location) generates correspondence effects with keypress responses [35, 45].

<u>23. More support for the account of spatial-coding as opposed to grasping affordance</u>

23.1 However, these findings by Tipper were not observed by Cho and Proctor which employed identical stimuli (in an object-centred condition): there was an absence of correspondence effects for both color and shape decisions [35, 45, 162, 167]. Furthermore, in one experiment, Cho and Proctor found a correspondence effect caused by handle location (i.e. the spatial-coding account) for color decisions in the base-centered condition [45, 162].

23.2 Lien (2014) have to assess if they would get alike results (i.e. correspondence effects) to Cho and Proctor for shape decisions in the base-centered condition [45, 162]. They also assess the potential for spatial coding and grasping affordance (if present at all) to be active together (a combined effect) when executing shape decisions (not color decisions) [45, 162]. If this assumption is valid, authors might anticipate a significantly greater correspondence effect in the base-centered condition for shape decisions in contrast to color decisions [45, 162]. The first experiment by Lien (2014) employed the tasks from Tipper's study (the same as those used in Cho and Proctor) [35, 45, 162, 167]. Lien demonstrates a correspondence effect (in terms of RT and PE) in the base-centred condition and not in the object- centred condition [45]. The results as a whole are alike to those of Cho and Proctor for colour decisions [45, 162, 167]. The first experiment of Lien (2014) used distinct apparatus, programmes and subject pools compared to Tipper [35, 45, 162]. Yet, they used identical stimuli and methodologies as Tipper but did not reproduce their results [35, 45, 162]. Also, in the base-centred condition, the correspondence effect was less for shape discrimination (assessed by Lien) compared to colour discrimination (assessed by Cho and Proctor) [45, 162]. Hence, the results described here are going in the reverse course to that anticipated by the grasp-affordance account and support the spatial-coding account [45, 162].

23.3 In Lien (2014), regardless of whether the decision involved shape (experiment 1 described above) or colour (experiment 2), in both cases the results were in general similar in terms of behavioural and ERP data [45]. There was an absence of a positive correspondence effect on RT and PE for the object-centred condition where as there was a big correspondence effect on RT and PE for the base-centred condition [45, 162, 167]. This finding goes against the grasping-affordance account and holds up the spatial-coding account [45]. In their second experiment, if the grasping-affordance view was true, the authors would anticipate a lack of correspondence effect in both conditions (base-centred and object-centred) since the task involves colour [45].

Going through some key studies

24. The Tucker and Ellis (1998) study: support for the affordance account

In their first experiment, Tucker and Ellis (1998) assessed the impact of an item's orientation and the optimal hand to execute an action of reaching-and-grasping [5]. A graspable item displayed in the center, can appear to be optimal for a grasp with the right or left hand when the orientation of the handle is to the right or left, respectively [5]. If the illustration of a visual item comprises action properties, like the favored activation of the hand optimal to execute an action of reaching-and-grasping, then it is anticipated that this activation would make easier trivial keypress responses performed by the congruent hand and, in contrast, hinder those identical responses performed by the incongruent hand [5]. They selected an item feature different from horizontal orientation as the parameter for choosing the response hand i.e. the inversion of the item (whether the item is upright or inverted) [5,45]. Therefore, the item handle horizontal orientation (to the left or right), and the grasp compatibility that is generated by its orientation, was not pertinent to the selection of the response but was regardless found to influence how fast the response was chosen and performed [5]. Thus, compatibility effects are anticipated from the association between item orientation (to the left or right) and the hand employed to execute the response, the latter being signaled by the inversion of the item [5]. In cases where the necessary response, established by the mapping and the item’s inversion, was with the right or left hand, RTs and PEs was smaller when the item's horizontal orientation was compatible with the action of reach-and grasp with the right or left hand, respectively [5]. In other words, it was observed that RTs were lower when there was a match between the handle and response hand compared to when they did not match [5, 45]. This backs up the view that some action-linked information (i.e. in this situation, the optimal hand to grasp the item) is illustrated automatically when the item is observed in the peripersonal surroundings [5]. This object-based correspondence effect is accredited to a grasping affordance where the displayed item activates in an automatic manner the hand on the matching side as the handle (as though the subject is truly attempting to grip the handle) [5, 45]. Hence, this supports that a motor response is activated in association to the handle employed to grasp the given item [5, 49]. Hence, coding is generated from the priming of particular actions that the item affords which, in this study, consists of reaching by a specific hand [5]. This study supports the account that the actions that a visual item affords are inherent to its illustration i.e. visual information comprises illustrating information regarding potential actions and in turn priming those actions [5].

<u>25. The Vainio (2011) study: the temporal features of the handle affordance effect and how such an effect differs from effects due to abstract visual features of items</u>

Handle affordances lead to a quick activation of the motor illustration of the hand that is most appropriate for grasping an item in terms of its orientation [29]. Hence, the handle affordance is used in Vainio (2011) [29]. These authors employed the handle affordance paradigm to examine if a negative priming effect (alike to the one in the masked-priming paradigm described prior in sections 15 and 16), can be linked with response activation generated by item affordances [29, 33]. In their first experiment, subjects had to respond to the left or right pointing central target arrow with a keypress response employing the left or right hand, respectively [29]. A prime mug (with a handle directed to the left or right hand) was shown prior to the target arrow [29]. The duration of the prime mug presentation (SOA) varied (30, 70, 170 or 370ms) [29]. After the disappearance of the prime mug, a blank screen was shown for 50ms [29]. Afterwards, the target arrow was shown for 70 ms and after the disappearance of the target, there was a blank screen until the response [29]. The mugs are not pertinent to the task [26, 29]. An incompatible trial implies that the orientation of the mug's handle is on the opposite side to the response hand where as a compatible trial implies that they are on the same side. An NCE (negative compatibility effect) implies task facilitation for incompatible compared to compatible trials where as a PCE (positive compatibility effect) implies task facilitation for compatible opposed to incompatible trials [29]. When the prime item was presented for short SOAs (30 or 70ms) before the display of the target, their effect was negative (NCE) [29, 37]. In other words, they demonstrated that if the handle information is observed for a short amount of time prior to the choice of the response hand, the handle information is linked with a negative S-R compatibility effect i.e. a NMHP (negative mug handle priming) [26, 29]. That is, there is a quick inhibition of the motor illustration that was activated at first by the handle affordance [29]. Also, when the item is presented for 370 ms, the findings are similar to those of Vainio et al. (2007) i.e. the NCE becomes a PCE [1, 29]. Around the 170 ms start of the prime item, the effect progresses from a negative effect to a positive effect [29]. They suggest that the handle affordance of the observed item generates the compatibility effects [29]. To sum up, their study suggests that observing a picture of a mug leads to the instant activation of the motor illustrations of the hand that matches the mug's orientation [29]. They state that if the mug is observed for a long enough amount of time, the mug will generate activation linked with the motor facilitation effect, even if the response choice occurs following the disappearance of the item [29]. Yet, this activation is quickly supressed if the mug disappears briefly after its display [29]. Here, the activation can not surpass the excitation threshold and it is supressed by the motor system [29].

The second experiment of Vainio (2011) served to ensure that the compatibility effects of their first experiment are linked to the item's handle affordance and not to abstract features of the item [29]. Their second experiment is exactly like their first with some exceptions [29]. Their second experiment used two distinct types of primes: 1) an altered variation of the prime mug (i.e. a novel prime stimulus which is a modified version of the mug with alike visual left-right biases as the mug) and 2) a variation of the target arrow that is larger in size [29]. The former prime involves the alteration of some visual features of the mug while keeping the salience bias linked to the handle [29]. Therefore, the novel prime includes alike left-right visual biases as the mug prime but is not recognised to be a mug [29]. They anticipate that if an NCE is also found (like in their first experiment) for these types of primes, then one can conclude that the effect is generated by abstract visual biases of the mug and not the handle affordance [29]. However, the NMHP disappeared when the mug prime was substituted for an altered abstract shape of the prime mug which generated a standard positive cueing effect [26, 29, 169]. That is, in their second experiment, the NCE of the first experiment was not reproduced i.e. for the novel prime, a PCE was found at 30 and 70 ms SOAs [29]. There was a lack of compatibility effects at the 170 and 370 ms SOAs [29]. In turn, when this prime is presented for 30ms, it generates positive priming effects if the prime has similar abstract spatial features to those of the target arrow [26, 29, 169]. On the other hand, when the actual prime mug shown for 30 ms offers handle affordance information, it generates negative priming effects regardless of the fact that it has the same important spatial features as the abstract shape of the altered mug [26, 29]. Hence, the authors conclude that the handle affordance of the prime mug from their first experiment is the cause of the NCE [29]. In other words, despite the fact that the left-right spatial components of the item are identical to those of the mug stimuli (in their first experiment), the elimination of the affordance parameter from the mug led to a common spatial PCE (which is usually seen with alike stimuli that are biased in terms of spatial location) [29, 38]. Vainio (2011) suggest that there is a motor factor to the NCE found in their first experiment (at the 30 and 70 ms SOAs) for their mug prime i.e. the handle affordance of the mug prime gave way to a clear NCE [29]. Also, their novel prime and their arrow prime (used in their second experiment) show PCEs and do not implicate affordances [29].

26. The Phillips and Wards (2002) study: the temporal features of an affordance effect when the prime item is irrelevant to the task

Phillips and Wards employ a design that allows them to assess the temporal features of any compatibility effect which could involve object affordance [25]. In the experiments by Tucker and Ellis (1998) (described earlier in section 24), the instructions were to categorize the orientation (upright or inverted) of the item leading to affordances [25, 5]. That is, the affording item was in all cases pertinent to the response (although its horizontal orientation was not) [25]. Phillips and Wards assess if these identical object affordances evoke action despite the items on their own not being pertinent to the ongoing purposes of the task [25]. In other words, they built a design where the prime object and the handle orientation (i.e., the display of its affordance for a grasp action) were non-pertinent to the subjects' task [25]. Therefore, in their first experiment, they try to reproduce the compatibility effects observed by Tucker and Ellis (1998) by, however, employing a design that isolates the display of an object prime affordance from the display of an imperative target [25, 5]. In turn, the authors could assess: 1) if the display of a non-pertinent affordance could generate response activation, and 2) the temporal features of that activation [25]. Here, they display a picture of a common graspable item as a prime display which has a handle oriented towards the left or right, but the prime is not pertinent for the task [25]. With distinct SOAs between the prime and target (i.e. between prime onset and target onset), the prime occurs prior to the imperative target which necessitates a keypress response with the left or right hand [25]. In their experiment, for every trial, there was a display of a picture of a "prime" object and a small central target (on top of the prime) in terms of vision, serving as a symbol for either left "I–IIII" or right "IIII–I" responses [25]. The primes were comprised of four pictures of a frying pan, for which the handle's orientation and depth simulate an affordance involving a left- or right-hand grasp [25]. In their experiments, subjects pressed the "z" and "m" key with the finger of the left or right hand for left or right responses [25]. The conclusions of their first experiment showed that there is a significant advantage in terms of RT when the handle orientation of the prime and the response hand correspond compared to when they do not (similarly to Tucker and Ellis (1998)) [5, 25]. The advantage for matching (between prime handle orientation and response hand) compared to non-matching trials increased progressively with SOA (over a period of 1200 ms) [25]. Yet, here, although the impact of correspondence may be accounted for by the activation of the "afforded hand"(i.e. the optimal hand for interaction with the item displayed in the prime), it could also be explained by an abstract response code in terms of space linked to the response side or a joint effect of both these views (the option of an abstract response code will be addressed later) [25].

27. The Ottoboni et al. (2005) study: a hand prime

In the Ottoboni, Tessari, Cubelli, and Umilta` (2005) study, the S-R compatibility paradigm was employed to examine if the picture of an observed hand can lead to the identity of the hand being retrieved in an automatic and covert manner [37, 170]. In this study, the picture of a left or right hand was displayed egocentrically (i.e. the perspective a subject would have of his own hands) and subjects executed a keypress response in regards to the color of a target dot displayed on top of the hand picture [37, 170]. This study demonstrated a negative or positive SRC effect when the hand observed egocentrically was displayed in palm view or back view, respectively [37, 170].

28. Vainio and Mustonen (2011) study: temporal features of SRC effects with a hand prime

28.1 Vainio and Mustonen (2011) employed a SRC paradigm (similar to Ottoboni et al. (2005) described above in section 27) to examine if the observed hand's identity (which is not pertinent to the task and displayed for a short amount of time) affects responses executed with the hand that is compatible or incompatible with the identity [37, 170]. Vainio and Mustonen demonstrated that a S-R compatibility effect alike to that generated by an item's orientation, can occur when subjects are shown a picture of a left or right hand displayed in an egocentric fashion [29, 37]. Their behavioral results back up the notion that this observed hand makes responses with the matching hand easier [33, 37]. In their first experiment, a target arrow was placed on top of the hand and subjects were told to perform rapid responses with their right or left hand in terms of the arrow's direction [29, 37]. In their experiment, the authors altered the time interval between the display of the hand stimulus and the display of the target arrow in order to assess the temporal features of the anticipated response activation generated by the observed hand (this SOA involves the actual duration of the hand prime) [37]. The temporal features of this positive SRC effect generated by the hand identity seems to grow from the 100 ms SOA (with the absence of any effect) to the 400 ms SOA [37]. That is, the authors demonstrate there is a strong activation of the motor system of the hand on the same side to the observed hand's identity when enough time was given for the effect to take place [37]. Hence, their positive SRC effects necessitates the prime hand being displayed for a greater amount of time (more than 100 ms) and staying visible until the subject's response [37, 29]. Indeed, in their experiments 1A and 3, when enough time was provided for the effect to take place (greater than a time interval of 100 ms between prime onset and target onset), the authors found a positive SRC effect and the effect stays for no less than 900 ms [37].

28.2 In their fourth experiment, they displayed a prime hand followed by a target arrow whose orientation subjects must respond to with the left or right hand [37]. This experiment shows that when the prime hand is shown briefly (80 ms) and disappears by the moment of response hand choice, there was a negative SRC effect (as opposed to their third experiment which showed a positive SRC effect when the prime is still displayed at the moment of response hand choice) [37]. Thus, the response activation which is, at first, generated by the prime hand is quickly inhibited if the activation is not unceasingly backed up by visual information of the earlier stimulus which served as a trigger [38, 136]. In other words, it is assumed that the NCE was due to motor inhibition processes that inhibit the incompletely activated and ineffectively updated motor activations [29, 37]. Also, they found a negative SRC effect in the SOA 1 condition (prime and target are somewhat overlapping in terms of their time course) and a decrease in the negative SRC effect for the SOA 2 condition (the start of the target was deferred for 150 ms) [37]. This supports the idea that motor inhibition linked with the prime hand's disappearance remains only briefly [37].

The Vainio and Mustonen study as a whole develops the identity-mapping model suggested in Shmuelof and Zohary (2008) i.e. hand identity is covertly examined from an observed hand and it is illustrated automatically in the subject's own motor system that matches the hand's identity regardless of whether hand stimuli are static pictures [37, 171]. In turn, this leads to the activation of the motor illustration of the hand on the same side as the observed hand's identity [37].

The results of experiments 1A and 3 in Vainio and Mustonen (2011) (where the PCE stays for no less than 900 ms) do not fit with the temporal features of the Simon effect where the response activation generated by the position of the stimulus is found to fade away following a time period of about 200 ms [37, 172]. Rather, the former findings are more alike to the temporal features of response activation generated in some studies (such as Phillips & Ward, 2002 described above in section 26) by the orientation of an item where the effect progresses steadily from 0ms to 1200 ms [25, 37]. Yet, Vainio and Mustonen (2011) demonstrate that the effect is greatest somewhere between 400 and 900 ms following the start of the prime hand after which it ceases to progress (Vainio et al. (2011) -described earlier in section 25- had a similar pattern of results) [29, 33, 37].

29. The Vainio (2007) study: the temporal features of an affordance effect where attentional resources are accessible for treating the prime item

Vainio, Ellis and Tucker (2007) had the key purpose of examining the attentional resources required for producing the object affordance effect [1]. Since the key goal of their experiment (which utilizes a similar paradigm to that of Phillips and Ward described earlier in section 26) does not involve the temporal features of the effect, the authors employed solely two SOAs (300 and 600 ms which implies different time intervals between the prime onset and the target onset) [1, 25]. Furthermore, Vainio (2007) employed colour instead of form (in the Phillips and Ward study) as a target parameter [1, 25]. In the first experiment, Vainio (2007) assess if the prime item which is not pertinent to the task can afford actions and lead to response facilitation in cases where attentional resources are completely accessible for treating the prime item during its display and despite the fact that the treatment pathway for form information is not necessary in the target discrimination task [1, 25]. In the first experiment, the stimuli included a black central fixation point within which was a grey cross [1]. The fixation point was then removed and substituted for a central prime item (which could consist of one of three general categories of objects with different object features) [1]. In turn, the fixation point appeared again at the same central location (as before the prime) on top of the prime item and subsequently changed into a target (a red or green dot) that was displayed in the center of the fixation point [1]. The subjects had the index finger of each hand on top of two response keys and they responded with the right or left hand on the right or left response keys to the colour of the target [1]. The experiment was designed to cue the subject's attention to the position of the target before its display [1]. An important aspect of their first experiment (as opposed to their second experiment) is that the prime item is at first displayed in the absence of a fixation point and hence in the absence of a target dot within the fixation point [1]. Therefore, the findings of the first experiment showed that the non-pertinent prime item orientation can prime responses that are compatible with the orientation despite the fact that attention is not required to be allocated to the item [1]. In other words, Vainio (2007) state that the sudden start of a focally displayed item that has features linked to action engages the subject's attention to an extent that is enough for building an action schema associated with the item [1]. Moreover, they demonstrated an orientation effect for items that are task-irrelevant despite the fact that the target discrimination task involves the treatment pathway for colour information [1]. Given that the modifications to the design of Phillips and Ward's (2002) study (by Vainio (2007)) do not affect the production of the affordance effect, the authors anticipate that the effect must be greater in 600 ms SOA compared to the 300 ms SOA which fits with the expectation by Phillips and Ward (2002)) [1, 25]. However, as opposed to what was anticipated, the findings here demonstrating that the orientation effect was decreased with a greater SOA, do not fit with the results of Phillips and Ward (2002) since the latter authors found the affordance effect to progress gradually with SOA [1, 25]. The opposing findings may be linked with the reduction in prime repetition (throughout different trials) in Vainio (2007) or the increased contribution of the pathway for treating colour (as opposed to form) to assess the target information in the experiment by Vainio (2007) [1]. We will discuss further conclusions made by Vainio (2007) in the arrow/dot discussion [1].

Alternate interpretations to the affordance account

30. Assessing the option of abstract spatial coding

Tucker and Ellis (described prior in section 24) do not preclude additional interpretations [5]. Specifically, it may be plausible that item orientation was ascribed in an automatic manner a spatial response code that is abstract and that this was the foundation for the seen effects [5]. In such a situation, the findings may be understood as a Simon effect of a stimulus dimension in terms of space that is non-pertinent to the task (item orientation in this experiment) [5, 60]. In fact, it is plausible that horizontal item orientation is coded on an abstract level as "left" or "right," in turn leading to an overlap with the response parameter and the automatic activation of the response [5]. Yet, this does not preclude the alternative option that response codes that are not so abstract are produced as well automatically with meaningful stimuli that are altered across parameters critical in establishing the manner in which individuals interact with the stimuli [5]. Hence, it is probable that any codes produced automatically by a visual item would comprise information regarding the association between the item and the subject's motor system i.e. this is the action potentiation view which involves the item's grasp compatibility [5]. To sum up, other than the account that the response code is associated to action-linked features of the stimuli [5, 11, 21, 62, 173-177], an alternative assumption is that SRC effects are due to the fact that the display of stimuli drives abstract response codes automatically which may affect response formation [38, 60, 62, 64, 178].

There is a method by which one could assess the relative impact (i.e. the effect item orientation has on the latencies of the response) of the two differing interpretations: 1) abstract spatial coding of orientation across a left-right parameter and 2) the automatic activation of a response code founded on the optimal hand for grasping the item [5]. This method (in the second experiment of Tucker and Ellis 1998) would be to assess a variant of their first experiment by employing a single hand [5]. If abstract spatial coding is valid, then an identical trend of findings should be demonstrated when the response is a keypress with the left or right finger of one individual hand [5, 179]. If, in contrast, the effect was generated only by the activation of a response founded on the optimal hand for grasping the item, then there should be a lesser effect or the lack of an effect in the task with a single hand [5]. The result of the second experiment was that there was a lack of substantial interaction (i.e. the lack of a correspondence effect) between item orientation (to the left or right) and response (to the left or right) in cases where one individual hand is used to perform responses [5]. That is, their two first experiments demonstrated that the non-pertinent orientation of a central item generated a compatibility effect on responses (to the left or right) performed by the left and right hands but not on responses (to the left or right) performed by two fingers of one individual hand [5]. Hence, there is a lack of compatibility effect of item orientation (to the left or right) when the association is solely relative between the item orientation (to the left or right) and the location of the responses in terms of space [5].

The two kinds of coding do not preclude one another but their findings propose that the compatibility effect of their first experiment has a low probability of being accredited to the coding of item orientation at the abstract level [5]. Rather, the authors assume that grasp compatibility is responsible for the effect demonstrated between horizontal item orientation and response hand [5]. There is support from other studies (such as studies involving visual extinction) for this option [180, 181]. In contrast, other authors contrasted the effect of SRC tasks with both hands and a single hand and demonstrated that the compatible mapping generated a benefit of identical size in both tasks [5, 179]. That is, disconnecting the left-right response locations from the effectors used to carry out the responses would have a negligible effect on the trend of findings [5]. In fact, according to certain authors, observing SRC effects depends on the position of the response locations (not the position of the effectors employed to execute the responses) [5]. For example, when mappings between the locations of stimulus and response are congruent, the RTs remain shorter compared to mappings that are incongruent even though the hands are crossed [5, 182]. Hence, the left or right response is generated by the right or left hand, respectively [5, 182].

31. Two possibilities for an effect generated by abstract spatial features of the prime item

In addition, in the first experiment of the Vainio (2011) study (described prior in section 25), one can not rule out that (instead of the handle affordance effect) the abstract spatial features of the prime item could generate the effects since the item's handle leads to a horizontally asymmetric picture [29]. This latter option could involve two possibilities that may generate the effect: 1) the prime mug's handle may have a shape with features similar to those of arrows (these authors used target arrows) and 2) there may be a spatial compatibility effect (i.e. a Simon effect) caused by the fact that the handle involves the highest saliency in terms of the horizontal view of the item [29, 38]. In the former situation, the NCE would be another form of the common masked-priming paradigm (described prior in sections 15 and 16) [29, 107] i.e. the NCE is due to the disturbance (by the short presentation of the prime arrow) of the visuomotor mechanisms treating the target arrow. Hence, in Vainio (2011) [29], the abstract visual features of the prime could lead to a shape similar to the prime arrow of the masked-priming paradigm [29]. In the second situation, a spatial compatibility effect could be generated by the item's handle which is the most salient component of the item [29, 38, 60]. For example, in one study, Anderson (2002) suggest that the behavioral effect could actually be due to shifting visual attention towards the feature of the item with the highest saliency or with the highest behavioral pertinence such as the handle [26, 56].

32. The Phillips and Wards (2002) study: support for a more abstract spatial coding as opposed to the action specificity view (the action affordance account)

The first experiment by Phillips and Wards was described earlier in section 26 [25]. In their second and third experiments, the authors assess whether: 1) the visual affordances of an item prime a precise response code for the hand or limb optimal to respond to the affordance (this is the action specificity view), or 2) the items activate codes in terms of space that are more abstract, which could prime a large array of responses to that side of the surroundings [25]. That is, the authors examined if: 1) the action illustration generated by the display of a visual affordance, primes a particular motor response bias for the limb optimal to execute the afforded action or 2) it evokes an interaction between representational codes that are more abstract produced by the S–R set as a whole [25]. In their second experiment (identical to their first experiment but with crossed hands), the advantage for matching (between prime handle orientation and side of response) compared to non-matching trials increase progressively with SOA, with a maximum at an SOA of 800 ms [25]. We should note that in this second experiment, the advantages of matching involved the response side and not the afforded response hand [25]. Hence, in their first and second experiments, the authors observed that greater time intervals (SOAs) between the display of the prime and response are inclined to generate greater correspondence effects [25]. Although the hands were crossed in the second experiment, the effects are similar to every significant finding of the first [25]. Therefore, the findings of this second experiment demonstrate that it is not a response with the ipsilateral hand (to the handle) that is primed [25]. These findings demonstrate in an obvious manner that a handle pointing to the left does not certainly activate left-hand responses [25]. In turn, this opposes the action specificity view [25]. Similarly to distinct response compatibility methodologies [183, 184], the key factor is the matching between components of the stimulus set and the actual location of the response [25]. These findings fit with the notion of an abstract response code, making all types of lateralized action easier, in contrast to priming a precise motor response for interacting with the affordance [25]. Yet, there may be an additional view of action specificity [25]. The authors have so far proposed that in terms of the action specificity view, irrespective of starting location, the left hand is optimal for a grasp of the handle oriented to the left [25]. Rather, it may be valid that any affordance effect could be more founded on "location" i.e. the hand positioned nearest to the item's handle may be the hand optimally afforded the action [25]. Therefore, in their third experiment, subjects pressed on switches with their right or left foot instead of making keypress responses with their left or right hands [25]. In terms of a coding view that is abstract, the method of response is mostly irrelevant, rather the important factor is that the matching between stimulus and response remains [25]. Given that the abstract coding view is valid, the authors anticipate alike effects of correspondence as those of the first and second experiments, irrespective of the modulation in the modality of the response [25]. In contrast, according to the action specificity view, despite the fact that the affordance proposed by the prime object could prime a particular response from the closest or optimally afforded hand, it is not probable to afford any particular action for a specific (or any) foot [25]. Hence, an action specificity view anticipates a lack of correspondence in this experiment [25]. The advantage (lower RTs and errors) for matching compared to non-matching trials rose with SOA, reaching a maximum at 800 ms [25]. Their findings reproduce the authors' earlier findings from the first and second experiments and they suggest that at least a certain kind of abstract coding view is valid [25]. In this third experiment, they support an abstract response code which makes an array of responses matching the handle location easier [25]. Since feet cannot manipulate items, their finding does not support the idea that action affordance (related to the item) leads to action potentiation and does not hold up the presence of the potentiation effect in terms of the TEC [25, 50].

33. The Vainio and Mustonen (2011) study precludes more abstract mechanisms

In Vainio and Mustonen (2011) (described in section 28.1), the PPE (i.e. PCE) was particular to the hand since it was not found when the subject used the index and middle finger of one hand to respond [33, 37]. The effect seems to be generated by a motor activation that is particular to hand identity (not by abstract mechanisms involving cognition or perception) [33, 37]. Also, irrespective of whether the hand was in palm or back view, the NCE did not change and, hence, the finding was not caused by some abstract spatial features of the stimuli but rather by motor effects [29, 37].

34. The Vainio (2007) study: support for abstract spatial coding

In their fourth experiment, Vainio, Ellis and Tucker (2007) assess if the orientation effect can be linked with abstract response coding by viewing the effect of item orientation on the choice of finger responses i.e. with the index and middle fingers of the main hand (other aspects of this experiment are identical to their first experiment described in section 29) [1]. They show that the abstract response coding view is backed up since responses involving the choice of a finger are influenced by item orientation [1]. That is, item orientation does not merely lead to affordances of responses of the hand best suited for a reach-to-grasp response towards an orientated item (such as a response with the left hand for a left-oriented item) [1]. Rather, item orientation generates a more abstract response code which can lead to an advantage as well for the selection mechanisms of the most suited hand i.e. both hand and finger choice is influenced by item orientation [1].

35. The Eimer study (78) precludes abstract coding

Prior to stating their conclusions (in section 12) regarding the masked-priming paradigm, Eimer evaluates some confounds (one of which we will mention here) [8]. Eimer established, via several studies, that the NCEs do not originate from central semantic levels but actually demonstrate response-associated processes that are generated inside the motor system [8]. In fact, they went against the postulation that effects are due to semantic mechanisms at a central level (such as abstract left or right codes that reflect the side of response without relying on the modality of the response) [8]. They made this conclusion due to the lack of NCEs throughout different modalities of response (such as responses with the hand compared to those with the foot) [8, 185].

36. The large variability of natural items employed support the action affordance account

The finding in Tucker and Ellis (1998) that the non-pertinent orientation (to the left or right) of a set of natural objects generates compatibility effects is a further argument that backs up the account that it is the significance of this feature for action that is responsible for the left-right coding [5]. The result with the highest importance in these experiments is the finding that compatibility effects, of a stimulus feature non-pertinent to response selection are observed with a large variability of natural items [5]. The visual features that establish whether the item is oriented to the left or the right are highly altered from one item to another, decreasing the probability for the production of an automatic abstract left-right stimulus code (this stands in opposition to the common Simon paradigm where it is the spatial position of the stimulus which generates the left-right codes) [5]. The lack of a compatibility effect in the situation where the subject must respond with a single hand in the second experiment by Tucker and Ellis 1998 backs up this notion [5]. Instead of item orientation producing in an automatic manner a left—right code in regards to the visual features of the item (i.e. a circumstance where they would anticipate compatibility effects in the second experiment), it is the grasping affordance by a specific hand that generates the binary left—right differentiation [5]. The finding that the compatibility association took place with a feature like item orientation is critical [5]. The orientation (to the left or right) was retrieved throughout the stimulus set, regardless of the fact that the perceptual input defining orientation was highly altered for every single item and, in addition, was not pertinent to the task [5]. Indeed, in common SRC studies comprising compatibility in terms of space, left-right codes are generated according to some fixed properties of the task presentation [5]. On one trial to the next, the property defining "leftness" or "rightness" is kept the same, making easier an illustration of the presentation that comprises left or right codes [5]. On the other hand, item orientation is not a fixed property in terms of vision of the presentation [5]. The trend of stimulation that cues an orientation (to the left or right) is quite distinct for every single item [5]. The finding that a compatibility effect was demonstrated in the first experiment, where the responses were performed with the left and right hands, can't in turn be accredited to a Simon effect founded on the coding of item orientation at the abstract level [5]. This interpretation does not fit with the elimination of the effect in the task with a single individual hand [5]. Rather, the second experiment proposes that it was the affordances for action that item orientation influences that generated the compatibility effect in the first experiment and not the orientation coding (to the left or right) on its own [5]. Likewise, the finding in the in Vainio (2007) (described in section 29) that different item categories (where items have features according to which the response code associated to orientation could be retrieved in diverse ways) did not demonstrate significant distinctions in the orientation effect proposes that the non-pertinent item primes hand responses that are most appropriate for a reach-to-grasp response in regards to the item, irrespective of the fact that item orientation is identified from distinct object features (such as the main axis of elongation or the location of the handle) [1].

37. Abstract coding is not ruled out

Views of SRC that comprise the actions primed by visual items do not substitute coding views at the more abstract level [5]. In fact, action-linked codes can extrapolate, instead of substitute, other coding views of SRC effects to circumstances where the variable dimensions have a natural relevance for action and are not fixed features of the presentation in terms of perception [5]. That is, although it is widely demonstrated that compatibility effects take place for spatial features of the stimuli when the responses do not comprise action affordances, abstract cognitive coding is not the sole kind of coding that response compatibility set ups can generate [5, 186]. Some authors suggest that there is a range of response codes that can be evoked, going from highly abstract codes to codes linked in a more direct manner to the actions that are rendered plausible by the visual surroundings [5]. This account fits with the neurophysiology of the visuomotor system, which back up the idea of a range of codes at several stages of abstraction, comprising the stages not influenced by the manner in which the responses are preformed (the most abstract stages) [5, 187].

38. Contrasting the TEC view with a more general stimulus-response compatibility effect

As opposed to the view that the potentiation effect is caused by covert motor simulations related to the TEC view, there could be a more general SRC effect (alike to the Simon effect) [38] due to the salience of various item areas (i.e. this effect relies on the allocation of attention to distinct item attributes) [50]. Regarding the ETC, the visual display of manipulable items automatically generates activity in various modality-specific cortices, which comprises motor illustrations that thus make motor responses quicker [27]. In contrast, the low-level attentional view suggests attentional mechanisms that bias responses to one area of space according to attended item features i.e. potentiation effects could be due to a more general SRC effect [27, 56, 166]. The more general SRC effect is supported by some studies such as Cho and Proctor (2010) who found a potentiation effect in response to a frying pan handle both for distinct hands or distinct fingers on one hand [1, 50, 166, 162]. These results are better interpreted by low-level visual attention and go against the ETC view [27]. Also, Cho and Proctor (2011) postulate that: 1) spatial compatibility effects can be caused by the handle or the spout of a teapot [50, 162, 167] and 2) in turn, a general SRC effect (not object affordance) causes the potentiation [50, 162, 167]. In fact, some behavioral research demonstrate that certain effects (such as quicker keypress response when there is a match between response hand and the handle of the manipulable item), may be optimally interpreted by low-level attentional effects (in line with a more general SRC effect) [27]. For example, Anderson (2002) used a task where the subject must make a keypress response with the right or left hand to a given feature and there is a left-right orientation of pictures of scissors and clocks [27, 56]. They found a potentiation effect i.e. shorter RTs when there was compatibility between response hand and the location of the handles of scissors and the hands of clocks [50, 56]. Hence, the effect with clocks can't be interpreted by the automatic activation of connected motor mechanisms since clock hands have high saliency but are not manipulable [27, 56]. It is probable that this is indicative of attentional mechanisms that have a partiality for keypress responses to one area of space depending on the item properties that are attended to (such as item handles and clock hands) [27].

39. Support for a more general SRC effect as opposed to the TEC view

In the second experiment of the Matheson study, they found potentiation effects (i.e. S-R compatibility effects) for both objects that are manipulable (artifacts) and non-manipulable (animals) [50, 27]. This opposes what was expected in regards to the TEC [28, 42, 50] which postulates that motor simulations must be automatically generated in response to the display of manipulable items (and not non-manipulable items) [28, 42, 50]. The motor simulation view can not explain that responses to animal stimuli was made easier since such stimuli are not linked to affordance-based grasping [50]. Thus, their second experiment where they find a potentiation effect for animal stimuli opposes the TEC theory as well as the implicit motor simulation of action affordances and supports more general SRC effects [5, 50]. In fact, Matheson examined the TEC assumptions regarding the potentiation effect [5, 50] and all their experiments back up the view that there is a more general SRC effect that explains the potentiation effect as opposed to the TEC view [25, 50, 56, 162, 165-167]. Yet, in support of the TEC, Matheson states that general theories of TEC are not opposed by their findings but simply that their findings support the fact that, using their methodology, the potentiation effect isn't indicative of automatic motor simulations [50].

40. Support for the low-level attentional view as opposed to the TEC view

Matheson (2014) assessed the P1 in response to targets dots that are cued in terms of space by distinct properties of items that are manipulable and non-manipulable [27]. On every trial, the cue (i.e. an image of a manipulable artifact or an animal) is displayed in the center of the screen, with a rightward or leftward orientation (for a time interval from 650 to 850 ms which was selected in a random manner for every trial) [27]. Afterwards, a black target dot was displayed close to the left or right side of the cue item without being placed on top of the cue [27]. The task involved a quick response with the left or right hand according to the side of the target dot display [27]. Hence, the target could be cued by: 1) the handle of the artifact, 2) the functional end of the artifact, 3) the head of an animal or 4) the tail of an animal [27]. In their experiment, animals are employed as controls since they are not manipulable but similarly to the manipulable artifacts, they have a strong left/right asymmetry when depicted in profile [27]. They assessed the P1 in response to the target as an indicator of initial partiality in terms of attention generated by the item orientation [27]. Hence, this study assesses if motor responses made easier by the manipulable items' handles are due to the automatic activation of motor plans by visual perception or due to partiality in terms of attention generated by the handles [27]. Their findings demonstrate that there were larger P1 amplitudes for targets cued by artifact handles compared to their functional ends [27]. On the other hand, there are no substantial distinctions between targets cued by the heads of animals in contrast to their bodies [27]. Similarly to the electrophysiological findings, there was greater accuracy for recognising targets cued by the handles of artifacts in contrast to their functional ends [27]. However, there was no difference in accuracy for animal heads compared to their bodies [27]. These results back up the view that implicit visual attention has a partiality for artifact handles [27]. However, they postulate that since the P1 is an early indicator of visual attention, it probably occurs before the activation of sensorimotor simulation in the motor or premotor cortices [27]. Due to this effect's latency, it is not probable that the potentiation effect (i.e. a quicker response to an identical spatial location as the handle) is indicative of the ETC view which involves the distribution of activation from the visual system to the motor cortex [27]. Instead, the early effect proposes that handles automatically engage visual attention and this partiality takes place at more initial stages [27]. Hence, the low-level visual attention view backs up the potentiation effect and goes against the ETC view [27]. As a side note, the authors did not find substantial attentional partiality to animal heads [27]. A potential interpretation is that animals have a high enough saliency as an item category that they draw attention as a whole, hence removing the partiality to one specific property [27]. Their P1 findings back up previous behavioral findings that demonstrate that visual attention makes manual responses faster when there is compatibility between the response hands and the salient item properties [1, 27, 50, 56, 164, 166]. The main viewpoint is that quicker responses using the limb that is in the identical spatial position to the handle of an item is indicative of initial attentional bias to that area of space [27]. As a whole, the authors demonstrate that the handles of artifacts lead to an automatic partiality of low-level visual attentional mechanisms that are linked with enhanced execution of the task involving the recognition of targets [27]. As a side note, they postulate that a history of reach-to-grasp responses to manipulable items enhances the saliency of the handle component of the item [27]. More studies should be carried out employing new items and training subjects to use these items in specific manners in order to establish the manner in which these partialities are generated [27].

41. The importance of the physical set-up of the visuomotor system and the human body

The coding (to the left or right) of item orientation suggested to underlie the compatibility effect in the first experiment by Tucker and Ellis (1998) (section 24) is founded on the physical set-up of the visuomotor system [5]. Orientation is an item feature that has to be illustrated appropriately to control actions, as opposed to what is necessary for item identification, in which case the effects of distinct reference frames can to be removed out [5]. The findings from the first and second experiments of Tucker and Ellis (1998) are associated with the left-right effector systems set up to interact with items in terms of vision, instead of a feature (to the left or right) intrinsic in orientation on its own [5]. In fact, extrinsic item features (such as orientation) are subject-based features in contrast to intrinsic item features (such as grip type) [11, 74, 157].The left-right set up of the human body is assumed to be the most important basis even of an individual's capacity to produce relative left right codes in terms of space [5]. In fact, the majority of affordances are defined by visual information with high complexity retrieved together with the subject's physical state [5]. In order to illustrate items that do lead to the affordance of particular actions, the coding has to comprise associations between the effector systems and the features of the items to which the effector systems are sensitive [5]. That is, knowledge of the options for action relies significantly on the association between the visual environment and the physical apparatus of the subject [5]. For example, in the case of spatial compatibility, what is relevant is the relative (not the absolute) location of the responses in regards to the stimuli [5, 188]. Indeed, previous research has demonstrated the relevance of relative (not absolute) coding in terms of space in demonstrating standard compatibility effects [5, 188, 189]. Moreover, not every action that can be performed in regards to an item can be performed in regards to the item if we assume there is a specific state of the subject [5]. For instance, one of the actions that can be performed toward an item is reaching and grasping, but this can't be performed if the item is outside the reaching space [5]. Hence, item location in regards to the subject will influence as well the actions with the greatest activation [5].

42. Contrasting the masked-priming paradigm with effects involving an item's handle affordance

The backward-masked priming (BMP) paradigm is the paradigm we have discussed earlier in sections 15 and 16 in regards to the review article by Eimer & Schlaghecken (2003) [8]. For the purposes of the thesis, we can consider the BMP paradigm synonymous to what is referred to previously as the masked-priming paradigm or masked-prime paradigm [8, 26]. In the masked-priming paradigm (BMP), the NPE (i.e. NCE) is demonstrated solely when the prime: 1) includes components that are pertinent to the current task (e.g. there is no negative priming if responses are made to letter targets and the primes are arrows), 2) it is followed by a backward mask and 3) it is displayed in a subliminal way [8, 26, 33, 107]. In regard to the second condition, the mask is essential in the effect since it generates the inhibition of the motor activation produced by the prime [33, 141]. In regards to the third condition, the effects are limited to subliminal primes that do not surpass the threshold of conscious awareness (i.e. they are effectively masked and presented for less than 60ms) while primes that can be observed mainly lead to positive priming effects (PPE) [33, 135]. Also, in regards to the first condition, the masked-priming paradigm supports the view (which is challenged and opposed in other studies described below) that motor activations generated by the visual features of the surroundings (like item affordances) which do not contain components that are pertinent to the current behavior will not lead to self-inhibition processes [29, 33, 107]. In Vainio et al. (2011) (described in section 25), the NPE (i.e. the NMHP) was demonstrated in other circumstances than the BMP: 1) the prime does not involve components that are pertinent to the task, 2) it is not followed by a backward mask and 3) it is not displayed in a subliminal way (there is a supraliminal display of the prime) [26, 29, 33]. Hence, Vainio et al. (2011) suggest that NPEs can be generated by items that are displayed for a short amount of time but are suprathreshold (due to the lack of a backward mask) regardless of the ongoing active goals and the task features, when the motor activation is generated by a realistic prompt for an action such as handle affordance [33, 29]. In other words, despite the fact that in Eimer and Schlaghecken (1998) [107] (i.e. in the BMP), the negative SRC effect was mainly demonstrated with prime arrows displayed for a short amount of time followed by a backward mask, lately studies have shown that an alike inhibitory effect can be generated as well by the affordance information of an actual object, without the backward mask when the object is displayed for a short amount of time [37, 86]. Therefore, in order to demonstrate negative priming with abstract primes displayed for a short amount of time that include components that are pertinent to the current task (such as the prime and target being arrows oriented in the same direction), it seems to be required that the subject is unaware of the prime, due to, for instance, the prime being followed by a backward mask [33, 133]. However, when response activation is generated by a naturalistic prime item like the picture of a hand (in Vainio (2011) [33]) or an item's handle affordance [29, 33], and the prime does not include components that are task-pertinent, the subject does not have to be unaware of the prime in order to find the negative priming [33]. In such circumstances, the prime does not interfere overtly with the target i.e. it does not overtly necessitate an identical or reverse response as the target [33]. Here, finding a negative priming solely requires that the activation is not robust i.e. it does not surpass the activation threshold (not to be confused with the "hypothetical inhibition threshold" described prior), for instance, because of the prime's short onset time [33].

However, the notion that, in the NMHP, the handle affordance could generate a quick motor activation of the matching hand fits with the motor self-inhibition interpretation [2, 26]. Indeed, one can potentially anticipate that, in the NMHP, there is an inhibition of precisely this early motor activation [26]. Another study by Vainio et al. (2013) also demonstrates the possibility that the motor self-inhibition processes (alike to those of the BMP) generate the NMHP [26, 33, 38, 190]. In fact, according to previous studies, if the NMHP (the finding in Vainio et al. (2011)) and the BMP share alike neural inhibition processes, it shows that the motor self-inhibition model is a universal motor occurrence found in everyday situations that lack artificial procedures like a subliminal display or a prime followed by a backward mask [26, 29]. However, the NMHP is more consistent with the negative priming phenomenon (which we will not address but is described in Vainio et al. (2014)) as opposed to the self-inhibition view [26, 84, 107].

43. The effect is not due to a fixed feature of the items employed

Similarly to the effects of item orientation on response hand in Tucker and Ellis (1998) (described in section 24), the results of Ellis and Tucker (2000) show the retrieval of action-linked features from an array of different visual features [21, 5]. The assumption is not valid that one individual property of every item is coupled with a specific action [21]. In other words, similarly to orientation effects, Ellis and Tucker (2000) state that (with respect to the effects they assessed involving grip type and wrist rotation) it is not probable that there is a fixed feature in terms of perception that can account for the inference of a pertinent code [21]. This notion on its own implies that these effects exceed the standard range of SRC effects, where a certain fixed feature (typically in terms of vision) is thought to generate an abstract stimulus code [21]. For instance, the location in the surroundings involves a ` left' or ` right' code [21]. Also, the negative priming effects found in Vainio (2014) for mug primes could be generated by multiple distinct types of oriented mugs (as shown in their second experiment) which shows that these effects are robust [26]. Moreover, the images employed in Vainio, Ellis and Tucker (2007) (described in section 29) included objects from three different categories which supports the fact that an item's orientation is identified from distinct item features (like the main axis of elongation or the position of the handle) [1]. Objects from each distinct category have features according to which the response code linked to the orientation can be retrieved in a distinct manner [1]. Furthermore, Ellis and Tucker (2000) mention that the effect of action priming by observed items are steady since they can be demonstrated with many kinds of actions throughout many distinct experimental methodologies [21, 5].

44. The impact of viewpoint/orientation of the item and semantic priming on the direct visual path to action and the semantic path, respectively

The Yoon study and experiments with healthy subjects propose two distinct mechanisms or paths implicated in action selection in regards to items that are visually displayed: 1) a mechanism implicating semantics that relies on the recognition of the item in our surrounding and then on action planning based on the acquired knowledge we extract (i.e. the semantic path) [159, 69, 191, 192, 193, 194] or 2) visual data can be employed to choose and control actions in a somewhat direct manner that does not rely on availability to semantic knowledge (i.e. the direct visual path to action) [159, 69, 195]. In regards to the latter mechanism or path, the brain reacts in a direct manner to potential actions supplied by items [196, 68, 69, 193]. In fact, there may be an advantaged availability to action knowledge from vision caused by acquired relations between objects and actions [159, 197]. This path in the brain may be due to action templates that item affordances activate [198, 159, 199]. Moreover, in support of the distinct paths, some neuropsychological studies support the idea that patients with a defect in semantic knowledge regarding single items can still complete actions with many steps like cooking [159, 200]. In Yoon (2007) [159], the authors examined the dual route notion which relies on distinct effects of two factors on categorization tasks involving either action or semantics: 1) the viewpoint of the item and 2) semantic priming, respectively [159]. The action decision task involves the subject choosing whether the item involves a twisting action or not where as the semantic task involves the subject choosing whether the item was a kitchen item or not [159]. These tasks were assessed in relation to items displayed in two orientations (i.e. viewpoints towards or away from the observer) [159]. Previous research demonstrates that item recognition is not sensitive to modulations in viewpoint in such circumstances [159, 201]. Indeed, Yoon found that the direct path to action (as opposed to the semantic/item recognition path) is more influenced by the viewpoint of the item in regards to the effector employed in the action [159]. That is, they found that the action decisions (not semantic choices) are influenced by viewpoint [159]. Therefore, Yoon (2007) proposes that action decision responses depend on a direct visual path to action which can be affected by the orientation of the item components (in regards to the subject) employed during an action (or the grip used in regards to items) ([193, 159]. In fact, in the Yoon study, there was a reduced activation of the visual path to action when the item component employed for gripping is placed away from the subject's right hand [159]. In other words, there is reduced efficiency (which considers RTs) and more errors (i.e. the action responses are more disturbed) [159]. On the other hand, in the action decision task, there is higher efficiency when items are displayed in an appropriate position for action (with the handle towards compared to away from the subject) [159]. The alterations in viewpoint are not great enough to affect availability to semantic knowledge and, in turn, the accuracy of semantic decisions [159, 201]. That is, availability to semantic information is resistant to the employed depth rotations of the Yoon experiments where the key components of items stayed displayed [159, 201]. In turn, all impact on action decisions by viewpoint is not caused by the fact that the viewpoint alteration led to the concealing of important components of items employed during identification [159]. Also, these findings go along with the idea that viewpoint affects action decisions in a somewhat direct manner that is not modulated by the previous availability of semantic knowledge [159]. Furthermore, earlier research also proposes that, when tasks emphasize information about action, visual information pertinent to action affects task execution in a more robust manner [193, 202]. In fact, Yoon (2007) have also shown that action judgments (as opposed to contextual judgments) are influenced by the proper orientation of items for action [193, 159]. In addition, Yoon (2005) observed that responses to items are influenced by the fact that the items are displayed as being appropriately or inappropriately gripped specifically when the task involves action judgments (there are less robust effects for contextual judgments) [193, 202].

In their second experiment, Yoon (2007) employed primes that are semantically linked (to the targets) to assess their impact on tasks involving action and semantic decisions [159]. An example of semantic priming would be a prime such as a wine glass displayed prior to a target such as a corkscrew [159]. Since, by definition, any direct path is not semantic, they found that tasks involving the semantic path such as semantic categorization (as opposed to the direct path involving action decisions) are more influenced by semantic priming [159]. Many studies support the idea that semantic priming can alter semantic processing [159, 203-209]. Yoon (2007) found that primes that are semantically related to the target (compared to unrelated primes) led to a semantic categorization with greater accuracy and efficiency [159]. Yet, in terms of accuracy and efficiency, action decisions were not influenced by semantic priming since semantic knowledge has a reduced impact on action decisions which implies a smaller probability of observing a semantic priming effect for such tasks [159]. However, semantic categorization relies on how fast availability to semantic knowledge is [159].

All of the above findings fit with the dual route view for choices of action [68, 159, 210]. In turn, in Yoon (2007), there is a kind of double dissociation founded on the fact that there are discerning impacts of semantic priming and viewpoint factors on semantic categorization and action decisions, respectively [69, 159]. This double dissociation points to the fact that ,for objects, there are two different paths (which do not rely on one another) from :1) vision to action and 2) semantic knowledge to action [159, 195]. However, a defect in one path (the visual path) can affect the employment of the other path to action (the semantic path) [159]. Some authors come up with a convergent route model where the two distinct paths are activated together to move the action choice system in the direction of a correct action for an item [159, 210].

<u>45. The impact of hand dominance</u>

The hand dominance may supersede the effect of horizontal item orientation in many situations of common grasping [5]. Hence, one could frequently reach for and grasp an item with the dominant hand despite the fact that its orientation is not most compatible with a grasp performed by that hand [5]. Yet, Tucker and Ellis (1998) mention that this does not influence their interpretations [5]. Despite the fact that in circumstances of common grasping, hand choice will seldom be completely established by item orientation, regardless, given a specific hand being used, the horizontal orientation makes grasping more or less compatible with that hand [5]. The horizontal orientation could be assumed to be more or less compatible with the signaled response hand regardless of whether or not that hand would have been used to grasp the item in reality [5].

<u>46. Support for a motor view of the effects as opposed to a perceptual view of the effects</u>

Occurrences such as the ‘repetition blindness’ [8, 211, 212] show that there is a perceptual bias counter to the repeated treatment of the same stimuli [8]. Hence, the NCE may be indicative of hindered target treatment in compatible trials in which case the target is a reiteration of the prime [8]. In order to assess this, authors employed experiments where a fraction of the compatible and incompatible trials include targets which are not alike to the masked primes and are displayed in distinct positions [8, 120, 121]. In these circumstances, NCEs are still generated which goes against the idea that the effects are interpreted by perceptual partiality [8]. Also, before establishing their conclusions (explained in section 12) with respect to the masked-priming paradigm, Eimer demonstrated, through various studies, that the NCEs do not come from perceptual levels but truly reveal response-linked mechanisms that are produced within the motor system [8]. Indeed, in other research, the priming effects of stimuli that are masked have been observed at stages of motor mechanisms according to electrophysiological studies that employed LRPs assessed over the motor cortex [111, 116, 213]. Due to results from electrophysiological research, some authors proposed a motor view of inverse priming effects [107, 111, 120, 214]. Furthermore, Schlaghecken and Eimer (2002) also suggest a comprehensive motor view of inverse priming effects [111, 123]. Moreover, response-linked views of inverse priming effects are supported as well by behavioral results [111]. For example, the second experiment of Klapp and Hinkley (2002) demonstrated priming effects of arrows on both types of targets (arrows and tones) i.e. this priming effect across multiple modalities (visual and auditory) supports that inverse priming takes place at the level of stimulus-response choice (not at that of perceptual mechanisms) [111, 124].

47. Assessing the effect of interactions between the prime and target which are perceptually alike

Mattler (2006) contrasted the effects of primes that are perceptually alike to the subsequent target and the effects of primes that are perceptually different but still congruent or incongruent with the target [111]. All their experiments demonstrated that priming effects are altered by the likeness between primes and targets in terms of perception [111]. In fact, their inverse priming effects appeared to rely solely on the likeness in terms of perception of primes with the target (displayed after the mask) [111]. However, positive target priming effects were observed with distinct primes (in terms of perception) [111]. Here, we will address how they came to these conclusions. In their first experiment, one could associate primes and targets in three manners: 1) alike forms in terms of perception, 2) distinct forms in terms of perception but congruent response connections (i.e. the response corresponding to the prime is the same as the response to the target) and 3) distinct forms in terms of perception but incongruent response connections (i.e. the response corresponding to the prime is opposite to the response to the target) [111]. If target priming effects are generated completely due to the prime and target interacting in terms of perception, then alike primes would lead to shorter RTs while distinct congruent prime trials would lead to larger RTs to a similar extent as incongruent primes [111]. In contrast, if distinct congruent primes make RTs shorter compared to incongruent prime trials, target priming effects can’t be simplified completely to the fact that prime and the following stimuli interact in terms of perception [111]. An alike trend of findings is anticipated in inverse priming conditions [111]. In their first experiment, the time delay between the mask and target (MT-SOA) was 0ms (without a mask) or 153ms (with a mask) [111]. For their 0 ms MT-SOA, RTs are shorter for alike primes in terms of perception in contrast to distinct congruent primes despite the fact that incongruent primes had longer RTs compared to congruent primes [111]. These results propose that priming effects in fact includes two components [111]. The first perceptual component of the priming effect is caused by the fact that the treatment of the target in terms of perception is made easier when the prime and target are perceptually alike [111]. However, the other component is not due to perceptual treatment being made easier since distinct congruent primes led to responses which became easier compared to incongruent primes [111]. This second component of target priming effects appears to take place at later stages of processing that are not influenced by likeness in terms of perception [111]. The latter results fit with those of earlier research that proposed that the target priming effect takes place at stages of the response system [111, 116, 213]. In the above study, for the 153 ms MT-SOA, inverse priming effects were observed but the results differed from those described above in regards to the 0ms MT-SOA [111]. RTs were longer for trials involving alike primes in terms of perception compared to trials involving distinct primes regardless of the congruency between the prime and target (i.e. the distinction in terms of RT between congruent and incongruent conditions was not significant) [111]. These results show that the perceptual interaction between prime, mask and target is the cause of the inverse priming effects [111]. Alike results to those by Mattler were demonstrated in previous research [111]. When arrow primes are used with arrow targets in a sequence of trials, the effects of inverse priming were demonstrated [111]. Yet, these effects did not occur in a sequence of trials where arrow primes are used with distinct targets such as letters [107, 111, 215] or other distinct response signals displayed laterally [111, 215], despite the fact that arrows are linked with the matching response through earlier practice [111]. Also, the effects of inverse priming did not occur with distinct stimuli in the first experiment of Eimer, Schubö, and Schlaghecken's (2002) [111, 185]. They employed arrow primes and the effects of inverse priming took place with arrow targets (not with different targets shown laterally) [111]. A similar evident effect of likeness between stimuli is demonstrated in the second experiment of Schlaghecken and Eimer (2000) where they employed arrow primes and the effects of inverse priming were greater on trials with arrow targets compared with different targets shown laterally [111, 121].

On the other hand, earlier research demonstrated effects of inverse priming in cases where an arrow prime occurs prior to distinct targets that are not arrows [111]. Arrow primes influenced the response to targets which are letters in Klapp and Haas's (2005) Experiment 2B where arrow targets and letter targets are displayed in a single block [111, 215]. Moreover, Klapp and Hinkley (2002) (experiment 2) observed inverse priming effects in the case where masked prime arrows occurred before, in certain trials, a target arrow and, in different trials, an auditory target [111, 124]. The result showing that prime arrows generate inverse priming effects during responses to auditory targets demonstrates that the inverse priming effects don't rely on perceptual likeness between the prime and target [111, 124]. An alike effect was observed in the second experiment of Eimer (1999) [111, 120]. Hence, in certain circumstances, inverse priming takes place regardless of likeness between the prime and the target and in other circumstances, it relies on this likeness [111]. Hence, there may be two kinds of inverse priming effects [111].

48. Contrasting the NCE-NP and the NCE-P

Some authors have suggested a difference between two kinds of inverse priming effects (i.e. NCE): the NCE-P (an NCE triggered perceptually) and the NCE-NP (a non-perceptual NCE) [111, 216]. According to previous research, the NCE-NP is found solely with a reduced prime visibility and it disappears when the prime visibility is enhanced [111, 216-218, 124, 135]. The results of the study by Mattler are associated with the NCE-P and emphasize a non-motor feature of this kind of inverse priming [111, 216-218]. This perceptual kind of inverse priming is alike to positive priming which is mainly not influenced by prime visibility [111, 113, 116, 216, 217, 140].

49. Introducing PPAs and addressing the semantic confound and the attentional bias confound

Symes, Ellis and Tucker (2007) assesses a possible origin of affordance (an item's orientation) and examines if it is an item feature that serves as a 'pure physical affordance'[198]. For the purposes of the thesis, OSC effects (orientation-dependent spatial compatibility effect) can be thought of as SRC effects that are specific to orientation and likewise to the SRC effects, when investigators simply mention an OSC effect, it implies a positive OSC effect (i.e. a benefit for matching over non-matching trials) [5, 6, 198]. Furthermore, when employing the term 'pure physical affordance' (PPA), the authors imply an affordance that is only demonstrated by the physical structure or organization of the item [198]. The actual existence of PPAs was not clear prior to their study [198]. Visual stimuli employed in earlier research have confused orientation in terms of PPAs with origins of affordances involving semantics and biases in terms of attention [198]. Indeed, a lot of behavioral research has demonstrated that an item's orientation is linked with effects of facilitation, hence backing up the affordance view [198]. Yet, features in terms of semantics and attention do not allow this research to support PPAs [198]. Employing cautiously chosen visual item stimuli, the experiments in Symes, Ellis and Tucker (2007) support the existence of PPAs regarding item orientation [198]. We will first address the semantic confound. They propose that previous types of experiments do not support PPAs, because the stimuli employed were mostly everyday household items that have evident action implications [198]. For instance, it is clear that the handle is the component of a cup in terms of function that has to be grasped [198]. Some authors proposed that picking up an item by its handle in a correct manner necessitates an interaction of cognition with action [198, 177]. Hence, these effects of facilitation could be due to the item's affordance in terms of function and semantics to a similar degree as possible PPAs [198]. Secondly, we will address the attentional bias confound. As some authors demonstrated, affordance experiments have typically assessed items that are not symmetrical in terms of vision [56, 198]. The authors proposed that it is probable for visual asymmetry to generate partiality in terms of attention, and in turn this partiality (which involves a move of attention to a particular position of the item) is the cause for the production of motor signals [198, 219, 220].

50. A general description of methods and findings of Symes, Ellis and Tucker regarding PPAs

The key goal of Symes, Ellis and Tucker (2007) was to assess the account that an item's orientation serves as a PPA [198]. They assessed this account by creating OSC conditions employing item stimuli that :1) lack any affordances in terms of semantics (they employed solely new items that are neutral in terms of function) and 2) involved a control for any regions with high visual saliency [198]. The fact that an item's orientation leads to the activation of elements of a reach and grasp action must be demonstrated in the RT and/or accuracy of keypress responses in terms of space (which to a certain degree imitate the commencement of a reach and grasp action with a specific hand) [198]. Also, they altered in a systematic manner the complexity of the items in terms of vision, in order to alter the robustness of their anticipated OSC effects [198]. They anticipate that the PPA would be more robust when the item seems to: 1) be closer to a real item, 2) be displayed in 3D and 3) be graspable [198]. Every experiment involved an identical elementary design: for every trial a visual stimulus (a rectangle or cylinder) was displayed centrally and rotated 45 degrees (in both directions) from the perpendicular [198]. The task involved a quick keypress response on the left and right (with the left and right hand) when the surface of the item depicted a 'wobbly' wood grain or a 'straight' wood grain, respectively [198]. Hence, item orientation was not at all pertinent to the task [198]. Furthermore, in order to address a second issue, they employed distinct SOAs to assess the temporal features of all demonstrated OSC effects [198]. In cases where the item's surface design was 'neutral' (the SOA stimulus), the subjects had to wait for the design of the item to be altered (following 0, 800 or 1200ms) into a wobbly or straight design (i.e. the target stimulus) [198]. Some studies support that the magnitude of OSC effects (defined as a benefit for matching over non-matching trials) increases linearly when there was an increase in the time where subjects observed the item (e.g. Phillips & Ward, 2002 described in section 26) [25, 198]. In other words, for responses in terms of space that have compatibility with the item orientation, RTs become shorter when there is a rise in the time where subjects observed the item [198]. Symes, Ellis and Tucker did not find an identical trend when employing visual stimuli with a control for aspects of semantics and attention (as opposed to Phillips and Ward that did not control for these aspects): they found that throughout all their experiments, the SOAs did not alter the OSC effect [25, 198]. In turn, one of their conclusions is that the temporal features of OSC effects evoked partly from semantic links between objects and actions are distinct from the OSC effects evoked from PPAs [198]. Moreover, based on all their experiments as a whole (with exceptions in some experiments for reasons that will be discussed), the authors demonstrated the presence of a PPA associated to an item's orientation (which does not involve affordances in terms of function or regions with high visual saliency) [198]. Particularly, they mostly (with exceptions in some experiments) found that the angle of an item's axis of elongation (i.e. its orientation angle) make responses compatible in terms of space easier [198].

51. The three first experiments of the Symes, Ellis and Tucker study

In their first experiment (with the basic design of all their experiments described in section 50), Symes, Ellis and Tucker (2007) employed an item that is simple in terms of vision as their oriented stimulus (a rectangle in 2D) [198]. The lack of OSC effect does not support the fact that the item orientation served as a PPA [198]. However, the observed dimensionality of an item can affect the type of actions a subject executes in regards to the item [221, 222], and shapes in 2D do not instinctively lead to the affordance of a large array of actions (according to Gibson's (1979) account, they do not lead to any affordances of actions) [12, 198]. On the other hand, items that do instinctively lead to the affordance of action in the actual world are 3D [198]. An item displayed in a similar manner to an item in the actual world (i.e. the item is 3D and graspable) could have a higher probability of generating an OSC effect [198]. In their second experiment, the rectangle in 2D (that led to a lack of OSC effect in their first experiment) was substituted with a cylinder that was evidently 3D [198]. The slight OSC effect they found is not assumed to be indicative of an affordance in terms of semantics (i.e. the cylinder lacked any semantic implications or components in terms of function like a handle) and there was a lack of possibility of attentional bias (i.e. the cylinder was visually symmetrical and there was an absence of properties or regions with high saliency that attention could be allocated to) [198]. Hence, they infer that when an item is displayed in 3D, the angle of its axis of elongation (i.e. its orientation) offers enough action-pertinent information to generate a slight PPA [198]. Next, in their third experiment, the complexity of the oriented item was enhanced by further orienting the cylinder 45 degrees around its centre in depth [198]. As such, the cylinder seemed to be pointing in the field in the direction of a specific hand, which would possibly lead to a stronger PPA in terms of item orientation [198]. A logical consequence of this rotation was that the cylinder was now visually asymmetrical, leading to a region with high saliency [198]. In turn, this experiment did not dissociate affordance from attention [198]. Regardless, due to the fact that the PPA is possibly more robust and visual attention could possibly be allocated to a region with high saliency, the OSC effect magnitude was two times greater than the magnitude in the second experiment (with symmetrical cylinders) [198].

<u>52. Assessing the impact of symmetry and contrasting the PPA with attentional partiality</u>

In order to elucidate the above findings, their fourth experiment contrasted the cylinders that are symmetrical with those that are asymmetrical inside one individual experiment [198]. With the goal of assessing if the distinct cylinders in their second and third experiments generated quantitatively distinct OSC effects, the authors contrasted these stimuli in a direct manner in this fourth experiment [198]. The cylinder symmetry/orientation/response three-way interaction proposed that symmetrical and asymmetrical cylinders did generate distinct effects: solely the cylinders that are not symmetrical generated an OSC effect [198]. Hence, this experiment backed up the assumption that asymmetrical cylinders should generate the greatest OSC effects [198]. The fifth experiment tried to assess the extent to which this is indicative of the possibly more robust PPA of orientation, or the partiality in terms of attention in regards to the region of the cylinder with high visual saliency [198]. The slight OSC effect of the second experiment was assumed to be indicative of a PPA of orientation instead of any attentional partiality, because the cylinders employed were visually symmetrical [198]. Yet, an effect of attentional partiality can not be precluded when assessing the greater OSC effects demonstrated with cylinders that are not symmetrical in the third and fourth experiments [198]. To assess this alternative, they replicated the third experiment with an added task involving detection created to assess the impact of the region of the cylinder that has high visual saliency [198]. In the detection task, a cylinder that is not symmetrical was displayed for a short amount of time (SOAs of 800 or 1200ms) after which a target dot was displayed on a single edge of the cylinder [198]. Once the subjects detect the dot, they execute a keypress response on the spacebar with both hands [198]. The two hands were placed over the space-bar, hence eliminating any spatial parameter of the response [198]. Given that visual attention is in fact allocated automatically to the region of the asymmetrical cylinder that has high saliency, then the RTs for the detection of the dots must be shorter in cases where the position of the dot matches that of the region with high saliency since attention should already be allocated to that position [198]. The magnitude of any spatial compatibility effect that relies on attention observed in the detection task can be contrasted in a direct manner to any OSC effect observed in the decision task (i.e. the same basic task as their previous experiments) [198]. Hence, this allows them to assess the relative impacts of attention and PPA [198]. Because the detection task did not support an attentional partiality towards the edge of the cylinder that has high saliency, the best explanation of the OSC effect involves an affordance-related view [198]. They propose that the OSC effects observed for cylinders that are not symmetrical (as found in the third, fourth and fifth experiments) were generated by the PPA of the cylinder's orientation [198]. The data of this study as a whole, back up their main expectation that there exists a PPA of object orientation [198]. That is, since the edge of the cylinder with high saliency does not seem to have an attentional partiality to any significant degree (as shown in their fifth experiment), they support an affordance-related view of the distinct trends of OSC effects observed when utilizing items that were altered in a gradual manner with respect to their visual complexity [198]. To sum up, they infer that PPAs can be present on their own, without relying on semantic links and attentional partiality [198]. As a whole, the robustness of the PPA seems to increase together with features of an item's display that instinctively lead to the affordance of actions (realistic, graspable and 3D) [198].

53. Getting back to the role of attention

It seems probable that any mechanisms in terms of attention that could have been linked with their OSC effects were allocated to an item, and not to a position (on the item) [198]. This supports other research proposing that the affordance of the orientation of an item that is manipulable is encoded in cases where attention is allocated to the item in its entirety, as opposed to, for instance, its handle [1, 198]. Hence, the authors do not infer from their paper that item affordances function in a void in terms of attention [198]. Rather, the authors postulate in other studies (Symes et al., 2005) [6] the probability that there is a close connection between mechanisms of attention and those of affordance [198]. The authors propose that visual attention is a process that is very relevant (and universal) such that it must be at a certain stage implicated in generating item affordances [198]. In fact, attentional processes frequently seem to be based on action, and it is likely that there is a required combination of 'selection-for-action' and 'selection-for-perception' [198, 223, 224].

VI. EXPERIMENT 1

INTRODUCTION

The goal of this experiment was to collect a norm of "grasp orientation agreement" (GOA) indicating to which extent people agreed to take an object with either the left or the right hand. We took a set of stimuli from the Bank of Standardized Stimuli (BOSS) [3, 4], selected the images of objects that fit certain specific criteria and asked subjects to decide with which hand they would pick up and use the object. The ultimate purpose was to employ the stimuli with the greatest agreement in the following experiments of the thesis.

A secondary exploratory purpose of this experiment was to assess the GOA separately for the three grip categories proposed by Vainio: 1) orthogonal handle (objects with handles orthogonal to the principal axis i.e., that did not range over the main axis of elongation), 2) elongated axis (objects with handles that ranged over the main axis of elongation), and 3) elongated shape (objects with an elongated shape that had no distinct handle) [1]. Examples of these grip categories are illustrated in Figure 6.1. Objects from each distinct grip category had features according to which the response code linked to the orientation can be taken out in a distinct manner [1]. For example, for the first grip category, it was the relative handle position of the objects that gave way to their affordance [1]. In the second grip category, both the position of the handle and the main elongation axis could have potentially led to responses linked to affordances with the hand that was optimal in terms of the orientation [1]. In the third grip category, the angle of the depicted object in terms of its elongation axis could have led to a response in terms of affordance with one hand or the other depending on how close one edge of the object was to a subject's specific response hand [1]. Furthermore, because they had no clear handle, objects with elongated shape like a cylinder were more ambiguous than objects with handles as to how and where they can be grasped [1]. The employment of three item categories allowed the assessment of whether the orientation of an item can be identified from distinct item features (such as the main axis of elongation or the handle location) [1]. This would be a crucial aspect in the orientation effect [1].

Other reasons that come to mind and which could explain why grasping differed across the three grip categories of objects include the fact that some grasps were more overlearned than others. This is the case for grasping objects with handles compared to the category of objects with elongated shape, such as a cylinder. The familiarity of the object can also affect the orientation of affordance. Familiar objects are more often used and will lead to a more automatic reach-to-grasp response. Thus, we expected a higher GOA for more familiar objects.

As a third exploratory purpose, we also assessed semantic categories. The reason we analysed our results in regards to the semantic categories is that not only the grip type has an influence on the results but also the semantic type of object [1, 6, 7]. In turn, the type of semantic object and the type of grip may interact. Indeed, some objects have a higher tendency of having handles and some types of handles may be overrepresented in some semantic object categories.

Hence, the results not only allowed us to identify the objects with a high GOA for our subsequent experiments and future studies but also allowed us to find the factors that influence the GOA such as the semantic category of objects, the grip type of objects and their familiarity.

METHOD

Subjects:

We asked 12 subjects (8 females) to participate in the experiment. All subjects were asked to sign an informed consent form approved by the Research Ethic Board of the Douglas Institute. Three out of the 12 participants were left-handed. The age spanned from 23 years old to 60 years old. The average age was 32.1 years old and the standard deviation was 10.1. Furthermore, all subjects reported they have normal or corrected to- normal visual acuity.

Stimuli and procedure:

The stimuli consisted of 467 object images. These images were taken from the Bank of Standardized Stimuli (BOSS), a set of 2762 pictures including 1470 pictures that have been normed in regards to the name, the familiarity, the visual complexity and the typicality [3, 4]. One can refer to the articles by Brodeur et al. (2010) and Brodeur et al. (2014) to access the BOSS images [3, 4]. The number of objects exceeded the number of concepts because some concepts had more than one exemplar. For example, there were 6 different umbrellas and 13 different forks. The number of objects included all object stimuli including the several images that depicted one kind of object (for example, we counted six objects for the six different images of umbrellas). The number of concepts only counted the number of different kinds of objects. For example, an umbrella was one concept but it involved 6 different images i.e. 6 different objects per se. That is, there were several exemplars for the same concept. Also, our objects were all very common items but they belonged to different semantic categories and these categories were normalized in the BOSS study [3, 4].

The images used for this experiment depicted : 1) orthogonal handles (objects with handles that did not range over the main axis of elongation i.e. the handles were orthogonal to the principal axis) (e.g. a teapot), 2) elongated axis (objects with handles that ranged over the main axis of elongation) (e.g. a knife) and 3) elongated shape (objects similar to a cylinder with an elongated shape that were positioned in a way that made them easier to grasp with one hand compared to the other) (e.g. a ruler) (see Figure 6.1) [1]. Only objects that could be grasped with a power grip were kept. Small objects grasped with pinch or precision grip, like a pencil, or large objects that could not be grasped with one hand, like a jackhammer, were not included in our stimuli set. We classified all objects as having their handle or graspable part oriented to the left or right.

Figure 6.1. *Examples of an object with handles that did not range over the main axis of elongation (the handles were orthogonal to the main axis) (the teapot), an object with handles that ranged over the main axis of elongation (the knife), and an object with elongated shape (the ruler).*

Subjects sat in a dimly-lit room about 50 cm from the computer screen. The stimuli were located at the center of the screen. We put 467 stimuli in an e-prime experiment where the subject was instructed that images will appear at the center of the screen and was told to choose whether they would use their right hand or left hand if they had to pick up the object very quickly. If they would use the right hand they would press 'm' and if they would use the left hand they would press 'z'. We gave subjects the example that if you are presented with a mug with a handle to the left, they would use the left hand. If the handle pointed to the right, they would use the right hand. The subjects were told to focus on the center of the screen throughout the entire experiment and to respond as quickly and as accurately as possible. The sequence of objects was pseudo-random and there was no inter-trial-interval. The images were displayed until the subject answered ‘m’ or ‘z’. The responses were recorded as well as their reaction time.

DATA ANALYSES

The “grasp orientation agreement” (GOA) was calculated for a given object by dividing the number of subjects that believed the object can be grasped with the right hand by the total number of subjects (12) and subtracting that result by 0.5. Hence, if we had an object with a consensus which involved all 12 subjects selecting the right hand to grasp the object, the GOA is 1 – 0.5 = 0.5 i.e. 50 %. If we had an object with a consensus which involved all 12 subjects selecting the left hand to grasp the object, the grasp orientation agreement is 0 – 0.5 = - 0.5 i.e. - 50 %. Hence, the positive GOA reflected a favourability for grasping the object with the right hand and the negative grasp orientation agreement reflected a favourability for grasping the object with the left hand. If we take the case where one half of the subjects thought the object should be grasped with the right hand and the other half thought it should be grasped with the left hand, the GOA would be 0.5 – 0.5 = 0 i.e. 0%.

In addition, we calculated a rate of GOA that was independent of orientation by averaging the absolute values (aGOA). The aGOA is calculated like the GOA except that all negative values were turned into positive values. For example, if all 12 subjects selected the left hand to grasp the object, the GOA will be -50% but the aGOA will be 50%, meaning that the agreement is equivalent to the agreement reached by 12 subjects selecting the right hand.

The analyses were essentially descriptive and used to characterize the stimuli. However, several analyses were conducted to see if the GOA and aGOA varied as a function of the grip categories and semantic categories. Analyses were performed on the concept rather than on the separate objects because we wanted each type of object to have the same weight. For example, the umbrella consisted of one concept with only one norm even though it was represented by 6 exemplars. We tried to assess the correlation between aGOA and familiarity. The familiarity scores were taken from the norms of the BOSS study [3, 4]. In order to calculate the familiarity scores, in the BOSS study, 39 subjects were told to rate on a scale of 1 to 5, how much they were familiar with the given object.

RESULTS

The 467 objects fitting our criteria included 206 different concepts. There was a mean of exemplars for each concept of 2.27 (SD: 2.12). Overall, 119 concepts had one exemplar and 348 had two or more.

Table 6.1 shows how the concepts were distributed across different semantic categories of objects [3, 4]. The kitchen utensils and tools categories included the highest number of different concept objects, followed by household article/cleaner and by skincare/bathroom item. The number of concepts was turned into percentages calculated relative to the total number of concepts in the BOSS in order to know which categories included the highest proportion of concepts with handles that fit our criteria and that could be included in the present study. As can be seen in Table 6.1, tool semantic category included the greatest proportion of concepts (47.3%) that had a handle. In contrast, the semantic categories of “Decoration & gift accessory” as well as “Natural element” included the lowest proportion of concepts (2.5%) that fit the stimulus criteria, thus that had a handle.

Table 6.1. *The number of objects and concepts used in experiment 1 for each semantic category as well as the associated kind of grips. Also, we show the number of concepts in the BOSS bank for each semantic category. We show the percentage representing the number of concepts used in experiment 1 relative to the number of concepts in the BOSS bank for each category.*

	Nb of objects (Exp.1)	**Nb of concepts (Exp.1)**				**Nb of concepts (BOSS)**	**% of concepts (Exp.1/BOSS)**
	All	All	Orthogonal grip	Elongated grip	Elongated object	All	All

Decoration & gift accessory	**3**	2	1	1	0	80	2.50%
Natural element	**6**	1	0	1	0	40	2.50%
Food	**7**	6	3	2	1	162	3.70%
Clothing	**15**	3	2	1	0	64	4.70%
Games toy & entertainment	**11**	5	0	5	0	67	7.50%
Building material	**5**	3	2	0	1	27	11.10%
Outdoor activity & sport item	**23**	11	0	10	1	94	11.70%
Stationary & school supply	**30**	7	5	1	1	59	11.90%
Electronic device & accessory	**27**	11	3	2	6	89	12.40%
Jewel & money	**3**	1	1	0	0	7	14.30%
Medical instrument & accessory	**2**	2	0	2	0	12	16.70%
Musical instrument	**13**	8	1	3	4	45	17.80%
Household article & cleaner	**38**	20	9	9	2	58	34.50%
War related weapon & item	**18**	14	0	14	0	36	38.90%
Skincare & bathroom item	**46**	18	2	11	5	45	40.00%
Kitchen utensil	**131**	50	19	28	3	117	42.70%
Tool	**89**	44	5	36	3	93	47.30%
All	**467**	206	53	126	27	1095	19.00%

Concepts were also counted as a function of the grip category [3, 4]. As shown in Table 6.1, the majority of concepts had an elongated handle, followed by the orthogonal handle and the elongated object. This pattern of results was found in most semantic categories of objects. In tools, the elongated handle was much more prevalent (36 out of 44) than the other grips. In kitchen utensils, the elongated handle was also the most prevalent (28 out of 50) but there was a higher proportion of concepts with orthogonal handle than in many other semantic categories. A chi-square was performed to test the difference between the kitchen utensils and the tools. Results showed that 1) the orthogonal handle was more prevalent in the kitchen utensils category compared to the tools category, 2) elongated grip was more prevalent in the tools category compared to the kitchen utensil category, and 3) elongated object had the same prevalence for the kitchen utensils category and the tools category (X^2= 8.820, p=0.012).

The objects were then examined as a function of their orientation and the hand that subjects thought they would use to grasp and use the object. To begin with, according to our own determination, we had 193 objects for which the orientation of the graspable part was to the left and 274 objects for which the orientation of the graspable part was to the right. In turn, we looked at the overall GOA. The overall GOA was 12.2%, meaning that there was a preference for using the right hand [5]. The GOA was positive for objects that were right oriented (orthogonal handle: 39.5%, elongated handle: 39.3%, and elongated objects: 30.2%) and negative for objects that were left oriented (orthogonal handle: -19.2%, elongated handle: -30.0%, and elongated objects: -2.7%).

The proportion of people using the same hand, whether left or right, to grasp and use the object, was also examined with the aGOA. This measure of consensus reached 33.6% for all objects. This average included 76 objects that had an aGOA of 50%, thus that were grasped and used by the same hand across all subjects. Right oriented objects had an overall aGOA (orthogonal handle: 39.5%, elongated handle: 39.3%, and elongated objects: 30.6%) equivalent to that of left oriented objects (orthogonal handle: 23.6%, elongated handle: 31.0%, and elongated objects: 17.3%). The aGOA was also examined for the kitchen utensils and tools because these semantic categories included the highest number of objects. Their respective aGOA of 36.0% and 37.3% were not significantly different.

Finally, we wanted to assess whether the aGOA varied in function to familiarity by looking at their correlations (Brodeur et al., 2010, 2014) [3, 4]. The correlation was not significant when including all concepts ($r=.023$, $p=.743$) or when limiting the concepts to those with an orthogonal handle ($r=.021$, $p=.884$), elongated handle ($r=-.018$, $p=.841$), or concepts representing elongated object ($r=.117$, $p=.560$). The correlation was also not significant for kitchen utensils ($r=.082$, $p=.566$). However, it was significant for tools ($r=-.359$, $p=.017$).

EXPERIMENT 1: Discussion

This study was primarily conducted to assess images of objects and determine which ones reached the highest consensus in regards to which hand would be used to grasp the object. In addition, the results were also examined as a function of different variables and three main findings deserve to be noted. First, kitchen utensils and tools were over-represented in objects that fit our criteria. For example, kitchen utensils and tools tended to have a handle or a graspable part. Almost half of the tools in the BOSS study satisfied our criteria [3, 4]. Secondly, the most prevalent grip was the elongated grip. It was more prevalent in tools compared to kitchen utensils and the orthogonal grip was more prevalent in the kitchen utensils. Thirdly, the overall GOA was 12.2%. The GOA was more positive for objects with a right handle or graspable part than it was negative for objects with a left handle or graspable part, meaning that the consensus for using the right hand on right handles was stronger than the consensus for using the left hand on left handles.

The results allowed us to identify a substantial number of objects for which there was a consensus. There were 14 objects that led to a unanimous decision as left oriented objects and 62 objects that led to a unanimous decision as right oriented objects. In Experiment 3 (arrow experiment) and Experiment 4 (dot experiment), we used only objects from this Experiment 1 for which the decision was unanimous for all subjects (i.e. 12 out of 12 subjects). In Experiment 2, we used objects for which at least 10 (or more) out of the 12 subjects selected the same hand to grasp the given object because this experiment required a higher number of stimuli and because stimuli were limited to tools and kitchen utensils. There were 316 objects for which at least 10 (or more) out of the 12 subjects selected the same hand to grasp the given object.

It is not surprising that tools and kitchen utensils were over-represented since given their nature, these objects are designed to be used with hands. In fact, these objects, particularly tools, are frequently used as stimuli in tasks involving affordances [2, 7, 44]. Tools included a higher proportion of items with an elongated axis. Such handles characterize mainly objects that require a specific manipulation. In contrast, there was a greater number of items with orthogonal handles in kitchen utensils. Again, this is not surprising since this type of handle essentially serves to support an object as would be the case for a coffee pot for example. Indeed, many kitchen items serve as containers i.e. a category in which orthogonal handles are over-represented. Also, we could postulate that tools tend to have an elongated axis since they involve more aggressive movements where as kitchen utensils tend to have orthogonal handles since they involve more balanced movements.

The overall GOA was 12.2%. This positive value is not surprising given the fact that the graspable parts of objects were more often oriented to the right than to the left according to our determination. In addition, the fact that the GOA for objects that were oriented to the left was less polarized compared to objects oriented to the right demonstrates that subjects tended to use their right hand even when the graspable part of the object was to the left [5]. Several reasons can explain these results starting simply with the fact that the majority of subjects (9 out of 12) were right-handed [5]. Three out of the 12 subjects were left-handed. When we compared the left-handed subjects to the right-handed subjects, more objects were unanimously classified as left-oriented (98 objects) for the left-handed subjects compared to the right -handed subjects (21 objects). Similarly, more objects were unanimously classified as right-oriented (190 objects) for the right-handed subjects compared to the left-handed subjects (77 objects). Hence, we can conclude that the dominant hand will influence the results i.e. the hand employed to grasp the object [5]. Furthermore, since there are more right-handed individuals in the general population, objects are usually designed to be better used with the right hand such as scissors for example.

VII. EXPERIMENT 2

INTRODUCTION

Experiment 2 was conducted to ensure that the objects selected from Experiment 1 produced significant affordance effects. This verification was a necessary step before assessing the activation and inhibition of affordances at various SOAs. As explained in the review, the affordance effect is indicated by the fact that subjects react more quickly (due to priming by the object) with the response hand that is congruent with the orientation of the object's graspable part. Therefore, a response with the right hand will take place more quickly if the object's handle or graspable part is towards the right compared to when it is towards the left. Interestingly, it was found (as in our experiment) that the affordance effect occurred even when the left-right orientation of the object's graspable part was not relevant to the task [2]. One classic experiment for measuring affordances was proposed by Goslin et al. [2]. Similarly to the Goslin et al. experiment (with some differences), in our experiment, subjects categorized each object as a tool by pressing one response key with the left hand or as a kitchen utensil by pressing another response key with the right hand [2]. As in our experiment, results demonstrated that the RT to the categorization were shorter when the orientation of the object's graspable part was congruent with the hand used to respond [2, 5]. The Goslin findings support the fact that there is a close association between vision (or perception) and action as suggested by the theory of embodied cognition (i.e. the visual system offers information in regards to the choices in behavior driven directly by visual object affordances) [2, 43]. Also, there is a connection between the action linked to a displayed object and the action a given subject plans to undertake and this connection can alter low-level visual mechanisms [2].

In our Experiment 2, we used an experiment alike to the one in the Goslin study [2]. We presented images of objects that can be grasped with the left or right hand while the task was to categorize these objects as tools or kitchen utensils. Hence, in this experiment, the object orientation was not relevant to the task but the object itself was relevant to the task given that the subjects must categorize it. The affordance triggered by each object was anticipated to prime the hand corresponding to the side of the grasp, as determined in Experiment 1, and fasten the response given with this hand for categorizing the object. Accordingly, using the right hand to categorize an object as a kitchen utensil should take less time if this object had its handle oriented to the right than if it was oriented to the left.

METHOD

Participants:

We recruited 15 subjects (11 females) to participate in the experiment. All subjects were asked to read and sign an informed consent form approved by the Research Ethic Board of the Douglas Institute. Three out of the 15 participants were left-handed. The age spanned from 20 years old to 61 years old. The average age was 33.87 years old and the standard deviation was 11.44. All subjects reported that they have normal or corrected to- normal visual acuity.

Stimuli

The stimuli taken from Experiment 1 were tools and kitchen utensils. Examples of tools are hammers and scissors. Examples of kitchen utensils are mugs and spatulas. Tools and kitchen utensils were used as the two categories for this experiment because in Experiment 1 involving the selection of stimuli, these two semantic categories contained the greatest number of objects and were among those with the largest aGOA (37.3 % and 36.0%, respectively) thus, with the greatest consensus relative to the hand that should be employed to grasp the object [3, 4]. The aGOA was not significantly different between the two categories. Moreover, the tool and kitchen utensil semantic categories contained the highest proportion of objects (47.3% and 42.7%) with a handle [3, 4]. Finally, the Goslin study which is quite similar to this second experiment also used these two categories [2].

Only objects with a GOA of 33% or above (i.e. for which at least 10 subjects over 12 would grasp the object with the same hand) were included in each category. Seventy-nine objects of each category that passed this criterion were selected. This number of stimuli was doubled after we created a mirror image of each object so as to have one version of the object that would normally be grasped with the left hand (i.e., the graspable part was oriented to the left) and another version of the object that would normally be grasped with the right hand (i.e., the graspable part was oriented to the right). This procedure doubled the number of stimuli which then passed to 158 per category. Thus, half of the kitchen utensils and tools had a left orientation and the other half had a right orientation. Hence, we ended up with 79 X 2 categories X 2 orientations = 316 images.

Several concepts had more than a single exemplar (i.e. many objects were exemplars of the same concepts). For example, there was two different spoons. We made sure we had almost the same number of exemplars across kitchen utensils and tools (i.e. the number of exemplars was balanced across kitchen utensils and tools). In the kitchen utensils, 5 concepts had 2 exemplars, 3 had 3 exemplars, 2 had 4 exemplars, 2 had 5 exemplars, 1 had 6 exemplars and 1 had 7 exemplars. In the tools, 6 concepts had 2 exemplars, 3 had 3 exemplars, 2 had 4 exemplars, 2 had 5 exemplars, 1 had 6 exemplars and 1 had 7 exemplars.

Procedure

Subjects sat in a dimly-lit room about 50 cm from the computer screen. The stimuli were located at the center of the screen. The task was programmed and administered on e-prime. The trial involved the display of an image of an object (either a kitchen utensil and a tool) to which subjects must respond without a time limitation. The next image appeared directly following the subject's response. The order of the images of objects was random. Subjects were instructed to press m (which is at the right of the keyboard) with the right hand when they saw a kitchen utensil and to press z (which is at the left of the keyboard) with the left hand when they saw a tool. The subjects kept their fingers on top of the keypresses throughout the experiment and were told to focus on the center of the screen. They were told to respond as quickly and as accurately as possible. No allusion to the orientation of the objects or its repetition in a mirror image was mentioned to the subjects. When the object orientation was to the right and the object was a kitchen utensil, the trial was congruent because the grip primed the hand that should be used for giving a correct answer. The same reasoning applied with tools oriented to the left. On the other hand, when kitchen utensil and tool were left and right oriented respectively, the stimuli were incongruent. There were 79 congruent trials and 79 incongruent trials in each category.

There was a practice session prior to the experimental session that allowed the subjects to practice and to familiarize themselves with the stimuli and the task. The experimental session was identical to the practice session and we only considered the results of the experimental session.

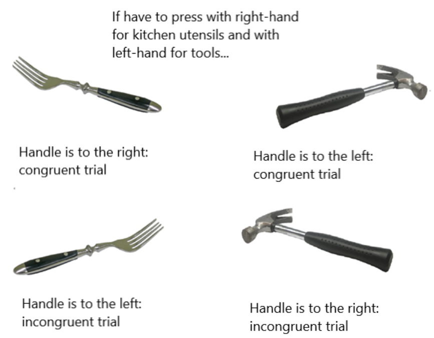


Figure 7.1. *Defining congruent and incongruent trials*

DATA ANALYSES

We used the repeated measures ANOVA of category (tools vs kitchen) x congruency (congruent vs incongruent) as within-subject factors for both the analysis of RTs and error rates. A congruent trial implied that the orientation of an object's graspable part was on the matching side to the hand used to categorize the image where as on incongruent trials they were on reverse sides [2]. In order to see whether the orientation of the object also had an influence on the performance, we ran a second ANOVA but with the orientation (left vs right) in replacement of the congruency condition. The analysis was conducted on the data after rejecting trials in the following procedure. Firstly, the incorrect responses were removed. We also removed the first trial for all subjects regardless of whether it was a congruent or incongruent trial. The reason for this removal of the first trial was that, after subjects pressed the spacebar at the beginning of the block to start the experiment, they were not completely ready to respond to the first trial which caused that first trial to have a more inaccurate RT and a longer RT than the rest of the trials. Thirdly, the trials with outlying RTs were removed. To do so, we calculated the mean and SD for congruent trials and removed all trials that are 2.5 SDs over or below the mean RT. We did the same thing for incongruent trials. As a whole, for all the different results analysis, we averaged the RTs that were left after the removal of the first trial, the incorrect responses and the 2.5 SDs from the mean.

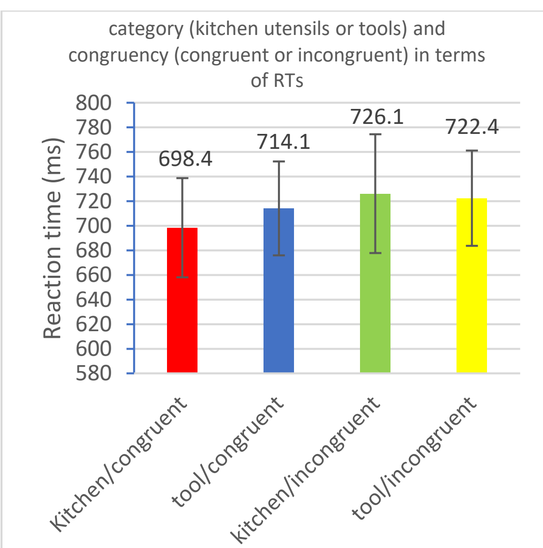
This rejection of trials was consistent with the procedure used by Goslin et al., as they assessed RTs for the correct responses and did not include responses that took longer than 1200ms or shorter than 200 ms or responses that were over or below the 2.5 standard deviations of the means [2].

RESULTS

It can be seen that the mean RTs to congruent trials (706.2 ms, SD:149.6) was lower than the mean RT to incongruent trials (724.3 ms, SD:166.5) leading to a difference of 18.1 ms (± 35.7) and this difference was significant (F (1,14) = 7.766, p= 0.015). The mean RTs for kitchen utensils (712.2 ms, SD:169.8) was lower than the mean RT for tools (718.3 ms, SD: 146.4) leading to a difference of 6.1 ms (± 50.0). As opposed to the congruency effect, this main effect of category was not significant (F (1,14) = 0.290, p=0.599). The category x congruency interaction was not significant (F (1,14) = 2.373, p=0.146).

On the other hand, the ANOVA performed to see if there was an orientation effect showed that that the right orientation (710.4 ms, SD: 150.9) had a mean RT that was not significantly shorter than the left orientation (720.1 ms, SD: 165.8) leading to a difference of 9.7 ms (± 49.4) (F (1,14) = 2.373, p=0.146). The category x orientation interaction was significant, F (1,14) = 7.766, p= 0.015. Hence, we decomposed the analysis and calculated t-tests. The mean RT for kitchen utensils/right orientation was 698.4 ms (± 156.2). The mean RT for kitchen utensils/left orientation was 726.1 ms (± 187.0). This led to a significant difference of (kitchen right – kitchen left) - 27.7 ms (± 39.1), t(14) = -2.745, p= 0.016. The mean RT for tools/ right orientation was 722.4 ms (± 149.9). The mean RT for tools/ left orientation was 714.1 ms (± 147.9). This led to a non-significant difference of (tools right- tools left) 8.3 ms (± 30.2), t(14) = 1.070, p =0.303.

Figure 7.2. (bottom/left) *Mean RTs (with standard errors) for: 1) kitchen utensils/congruent trials, 2) tools/congruent trials, 3) kitchen utensils/incongruent trials and 4) tools/incongruent trials.*



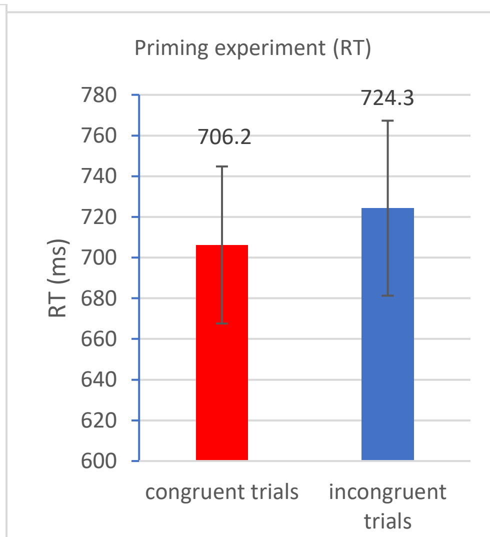
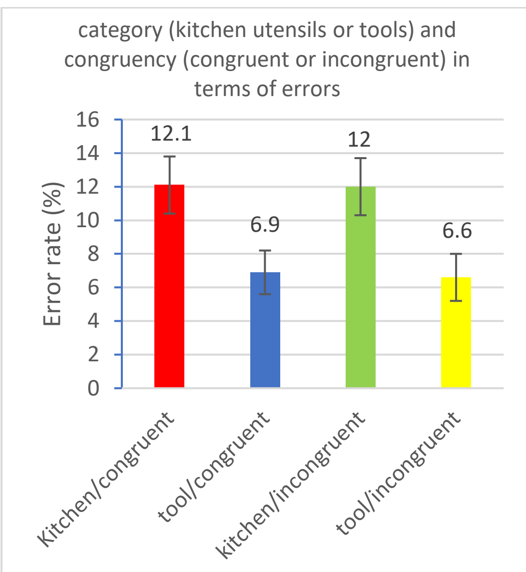


Figure 7.3. (top/ right) *Mean RTs (with standard errors) for congruent trials compared to incongruent trials.*

It can be seen that the mean error rate to congruent trials (9.5 %, SD: 4.9 %) was not significantly greater than the mean error rate to incongruent trials (9.3%, SD: 4.3 %) (F (1,14) = 0.091, p-value=0.768). In terms of category, the mean error rate was greater for kitchen utensils (12.0 %, SD: 6.3 %) compared to tools (6.8%, SD: 5.0 %). The main effect of category was significant (F (1,14) =7.852, p-value= 0.014). In terms of error rates, the repeated measures ANOVA of category x congruency was not significant F (1,14) = 0.053, p-value= 0.821.

On the other hand, the ANOVA performed to see if there is an orientation effect showed that that the right orientation (9.3% SD: 4.5 %) had a mean error rate that was not significantly lower than the left orientation (9.5% SD: 4.5 %), F (1,14) = 0.053, p=0.821. In addition, the category x orientation interaction was not significant, F (1,14) = 0.091, p= 0.768.

Figure 7. 4. (bottom/left) *Mean error rates (with standard errors) for: 1) kitchen utensils/congruent trials, 2) tools/congruent trials, 3) kitchen utensils/incongruent trials and 4) tools/incongruent trials.*



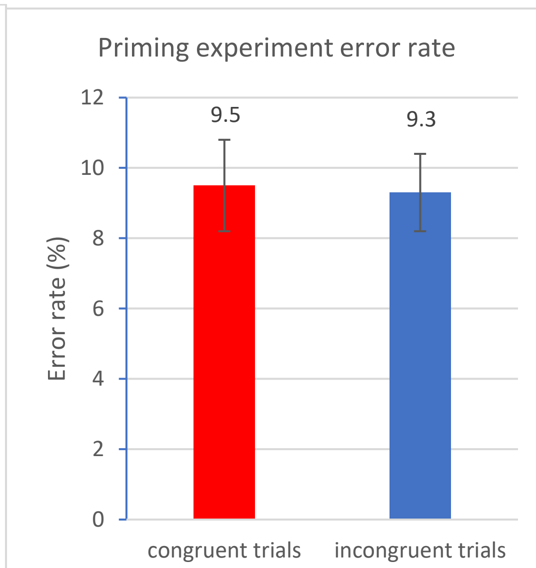


Figure 7. 5. (top/right) *Mean error rates (with standard errors) for congruent trials compared to incongruent trials.*

EXPERIMENT 2 DISCUSSION

<u>Our general findings</u>

Our main findings are the following: 1) in terms of error rates, the incongruency does not lead to more errors as there was no significant difference in error rates between congruent compared to incongruent trials and 2) we saw shorter RTs for congruent compared to incongruent trials as there was an effect of congruency for RTs. One possibility for not finding the effect in terms of PEs is that the amount of errors was not large since the presentation of our stimuli were not short (i.e. they were shown until the response by the subject) and the stimuli were not masked [159]. Also, our subjects categorize tools slower but with greater accuracy (i.e. there is a trade-off between RT and errors) compared to kitchen utensils [50]. This finding is similar to Matheson (2014) where subjects categorize artifacts (in contrast to animals) slower but with greater accuracy [50].

Contrasting our results to those of other experiments

We support stimulus-response compatibility effects and affordances

Our results also support the same conclusions as other studies that employed stimulus-response compatibility paradigms: subjects deliver a quicker classification of items when there is congruency than when there is incongruency between their motor response and the response linked to the affordance of the given item and, in turn, one can assume that affordance is offered by visual items [2, 5, 175, 225]. These effects were found for: 1) the hand employed (as in our experiment) [2, 5], 2) the wrist rotation and 3) the shape of the hand [2, 21].

We found an object-based correspondence effect and we support affordances

As in Goslin, our results support the fact that there is an association between the action linked to a displayed object and the action a given subject plans to undertake [2]. This association can alter low-level visual mechanisms [2]. That is, as in Goslin and Tucker and Ellis (1998), our behavioral results support the notion that there is a lateralized affordance-driven priming effect [2, 5] i.e. there is a facilitation (shorter RTs) of action when there is congruency (i.e. a match) between the item's handle (graspable part) orientation (which is task-irrelevant) and the intended response hand (the location of the response) and an inhibition effect (longer RTs) when there is incongruency (i.e. no match) [2, 5, 44, 163-165]. This is called the object-based correspondence effect (i.e. the presented item automatically activates the hand on the corresponding side as the handle) and we conclude (as in Goslin) that it is caused by object-based attention [2, 5, 44, 45, 47, 48]. Hence, similar to previous studies, this takes place as though our participant is actually trying to grip the handle (even if our participant only actually makes keypress responses) [5, 45]. Similar to previous research, given that our handle orientation is irrelevant to the task, we could back up the fact that item affordances are automatically activated i.e. there is an activation of a motor response in connection to the handle utilized to grasp the item [5, 45, 49, 50]. Hence, based on previous studies, we can support the ideas that: 1) an item's graspability is a critical characteristic for generating a visual affordance and 2) execution is altered by the placing of the object relative to the hand with which the subject responds [5, 11, 49, 226-230]. As in Goslin, our results show early processing of visual-spatial attention [2, 44]. We should note that in our experiment as well as in the Goslin study, an object-centred condition (described in section 20 of the review) was employed [2, 44, 162]. To sum up, our experiment supports the potentiation effect i.e. that the handles of items can potentiate a hand response using keypresses to a congruent location [50]. As a side note, in our experiment discussed here, the item is a target for action given that the subject must categorize the item but, as will be discussed in regards to our arrow and dot experiments, focusing attention on an item can give way to the activation of motor illustrations even though the item is entirely not a target for action since the subjects only respond to following targets [5, 7, 11, 153].

Our effects could be influenced by the nature of the task and the subject's purpose

Our potentiation effect (in our categorization task) could be influenced by the requirements or nature of the task and the subject's purpose can affect the potentiation effect [50, 52]. For example, in the Matheson study (described in section 39 of the review) when subjects execute an overt categorization task as opposed to a task involving orientation, there was a reversal of the potentiation effect [50]. The Salmon study also provides a strong example for the fact that the nature of the task (a naming/identification task vs a categorization task) could impact the results by causing a significant reversal of their effects [52, 231-234]. Moreover, other authors found: 1) the potentiation effect to be present when the task involved a discrimination of shape but not of colour and 2) their potentiation effect was greater when ongoing action was hinted at by the handle's depiction [35, 50]. Furthermore, certain authors state that different actions (such as grasping or pointing) give way to distinctions in the way distinct parameters (such as size or location) of visual stimuli are taken into consideration during the selection mechanism [181, 235, 236]. Based on earlier research, the goal or intention of our subject for action would influence: 1) the degree to which the environment (i.e. our item displayed on the screen) gives way to an action affordance and 2) the manner in which visual selection operates and how attention is allocated to visual displays (i.e. the types of visual data the subjects concentrate on) [12, 181, 235-237]. That is, if the subject had a different intention or goal, the same item (i.e. surrounding) would not be expected to generate the same action-associated response [12, 181]. Since we don't have a control condition to compare the results with a different task, we can only suppose the impact of the requirements or nature of the task on our potentiation effect [52, 196, 181, 237]. Based on the above findings, we could postulate that the automatic generation of the potentiation effect does not occur in all tasks and our results may be due to our precise methodological features [50, 35]. Moreover, in our experiment, the effect of the task on potentiation is generalized and does not influence one category of objects more than the other due to the fact that the interaction of category and congruency is not significant. Also, as mentioned in the Matheson study, the task can alter the degree of activity of sensory-motor processes generated by manipulable objects [50, 238]. Such activity plays a role in our effects. Some parts of cognitive mechanisms such as our categorization (in contrast to others like identification) lead to a greater employment of motor simulations [50].

Do our results fit with the TEC account?

As in earlier research (by Goslin, Matheson and other studies) in favor of the TEC, our RT results could support the TEC account and its postulations (described in section 4 of the review) and the fact that, as explained in other studies, the potentiation of the response is due to focusing visual attention on the graspable attribute of an item [2, 44]. Similarly to what is explained in the Matheson study, our experiment which includes ‘action potentiation" can back up the perception to action connection [50]. However, we can not preclude arguments by other studies that oppose the TEC and could explain our results such as the Anderson, Yamagishi and Karavia (2002) and Phillips and Ward (2002) studies (described in sections 4, 42 and 48 of the review) [5, 25, 50, 56].

Matheson's second experiment (described in section 39 of the review) goes against the TEC account and some of its postulations due to the fact that they found potentiation effects with animal stimuli [27, 43, 51]. Since we did not use animal stimuli as a control (we only used artifacts), we could not assess whether we would find a potentiation effect for animal stimuli [51]. Hence, we can not conclusively oppose or back up the TEC view [28, 42, 50].

As a side note, the fourth experiment of Matheson (addressed in section 39 of the review) contrasted two categories of items: artifacts and animals [50]. Their main effect of category for RTs may be significant since artifacts are manipulable where as animals are not where as both our kitchen utensils and tools are manipulable leading to a lack of main effect of category on RTs [50].

Our results may be due to a more general SRC effect as opposed to the TEC account

If we base ourselves on the three first experiments of the Matheson study, we could also suggest that our potentiation effects could be due to a more general SRC effect (described in section 38 of the review) as opposed to the TEC account [1, 5, 25, 50, 56, 162, 164-167, 35]. However, it is most likely that our results support the fact that: 1) the compatibility effect is due to the orientation of the object (particularly its handle) and 2) object affordance is the cause of the potentiation effect [50, 162, 167]. To sum up, our findings could potentially be explained by two accounts described in section 30 of the review: 1) a response code linked to action-related attributes of the stimuli [5, 11, 21, 62, 173-177] or 2) a more abstract response code [38, 60, 62, 64, 178].

Our effects may be due to the asymmetry of the items as opposed to the affordance account

The alternative explanation to the affordance account implies that in our experiment (and as supported by other studies), it is possible that the correspondence effect is caused by asymmetries in the visual features of items in contrast to the handle's grasping affordance [45, 239]. Hence, we could postulate that there is an attentional bias to salient components of asymmetrical objects [50, 56]. Anderson, Yamagishi and Karavia (2002) (section 38) make this postulation in regards to a clock stimulus (that is not manipulable) [50, 56]. Matheson (section 39) makes the same postulation and implies that the handles of artifacts and the heads of animals are striking to visual processes [50, 56]. In turn, the handles (or graspable parts) of our stimuli could be striking to visual processes [50, 56].

Is our effect due to an automatic activation of the response by a grasping affordance?

Likewise to observations made by some authors, it is possible that there is no automatic activation of our response by a grasping affordance [45, 240]. This would imply that our potentiation effect is driven by attention (many authors make this postulation) [50]. For example, Vainio, Ellis and Tucker (2007; Exp 2) observed that their potentiation effect disappears when attention is allocated to components of the object that are not pertinent [1, 50]. In turn, this finding: 1) potentially opposes the fact that the potentiation effect is automatic and 2) supports the fact that early mechanisms related to attention or vision are involved [1, 50]. One option is that our categorization task involves attention being focused on pertinent components of the object which would not require the effect being automatic. On the other hand, we should point out that many other studies do support an automatic potentiation effect. The fact that our object's affordance is irrelevant to the subject's goal (i.e. a semantic categorization task) could support the automaticity of our effect.

Assessing a control could clarify the presence of a more general SRC effect

As mentioned prior in the discussion, we only employ items that are manipulable and it would be useful to assess a non-manipulable but asymmetrical control stimulus (such as animals displayed in profile) that would be anticipated to lead to an absence of motor simulations [50, 56]. This is also the case in most other studies apart from studies such as the Anderson, Yamagishi and Karavia (2002) study and the Matheson study [25, 50, 56, 162]. Therefore. the chance remains that the salient components of our asymmetrical objects attract an attentional bias (as opposed to the action affordance view) [50, 56]. Indeed, manipulable objects (not animals) should generate the potentiation effect if that effect is influenced by object affordances [28, 50]. In contrast, the two kinds of items should generate the potentiation effect (although in relation to an unidentified component of the item), if that effect is influenced by a code pertinent to location linked to some component of the item [25, 50, 166]. Since we did not assess the potentiation effect for animals as a control, we could not rule out the more general SRC effect where the RT would be less when the response hand and a salient item feature would be compatible for artifacts as well as animals [50]. Indeed, the second experiment of Matheson (2014) (described in section 39 of the review) serves to differentiate between the action affordance view and the more general SRC effects and end up supporting the latter option [5, 50]. Thus, our potentiation effect could be interpreted as a rapid attentional partiality associated with the recognition of our artifact handles [50, 241].

General SRC effects can be generalized across multiple distinct items and affected by the nature of the task

Similarly to Matheson (2014), our general SRC effect can be generalized across multiple distinct items since we used several different objects as stimuli [50]. Also, as mentioned earlier and as in Matheson (2014), the effect can be affected by the nature of the task [50]. That is, the potentiation effect could be modulated by altering the salience of various item areas through transformation of the task requirements [50]. Therefore, likewise to what was described previously in the discussion, Matheson assesses the notion that the nature of the task can affect the attentional biases [50].

Our effect differs from the Simon effect

According to the affordance view, our compatibility effect is due to object orientation (of the graspable component) and not due to the location of the object in space and thus our experiment does not involve the Simon effect per se [38, 50, 2, 44, 165-167]. In other words, as opposed to the Simon effect, we did not assess item location but rather item orientation since we displayed central objects that differed in regards to the orientation of the graspable part and we did not alter the actual location of the objects [7, 60, 63]. Hence, as opposed to the Simon effect, we could support the affordance account and our effect (a micro-affordance effect) could be due to object grasping affordance and not stimulus location [5, 11, 45, 59-62]. Yet, as in Matheson, we could alternatively postulate the more general SRC effect (described in section 39 of the review for their animal items) which can be considered alike to the Simon effect: there can be attention to distinct areas of items [38, 50]. Thus, in our experiment, it is possible (as postulated by Matheson) that the fact that attention is allocated to various areas of an item leads to a more general SRC effect (like the Simon effect) which is not impacted by motor simulations evoked by afforded actions [38, 50].

We still can not preclude the TEC account and the generation of motor simulations

Yet, similarly to what we state in section 39 of the review regarding Matheson's stand with respect to the TEC, we still can not completely preclude the TEC theories and their assumptions including automatic motor simulations [50]. In fact, as opposed to basing ourselves on Matheson (2014), if we base ourselves on Witt (2010), we could propose that: 1) motor simulations are produced by observing our manipulable artifacts and 2) these simulations facilitate the treatment of the items (such as our categorization of items) [28, 50]. In turn, based on Witt (2010), we would not expect congruency effects on RTs for animal stimuli since there is a lack of motor simulations [28, 50].

We employed an object-centred condition to support affordances

The object-centred condition of Lien's third experiment (described in section 20 of the review) is alike to our object presentation except for color and size [2, 44 162]. Similarly to Tipper and as opposed to Lien's results (both described in sections 28, 29.2 and 29.3 of the review), in our experiment (where we did not assess the base-centred condition), we find an overall big and positive correspondence effect for RTs (but not PEs) in the object-centred condition (despite the fact that it does not have a spatial code) which is indicative of the affordance being the cause of these effects leading to the validation of the grasping affordance view [35, 44 45, 162]. In contrast to our results, Lien demonstrated a strong significant correspondence effect solely in the base-centered condition (not the object-centred condition), and infers that the spatial-coding view is valid and goes against the affordance view [44, 162].

Spatial coding and grasping affordance could be active together

In terms of RT (not PEs), our experiment supports the affordance account since we found a strong and significant correspondence effect for the central location condition where as , in terms of RT and PEs, the second Lien (2013) experiment (described in section 21.1 of the review) as well as their findings for the pooled results of the central condition across their three experiments (described in section 21.3 of the review) support the spatial-coding account since they found a correspondence effect only for the peripheral location condition and not the central condition [44, 162, 165-168, 2]. However, we did not assess correspondence effects for peripheral items (as opposed to Lien's second experiment which did) [44, 162, 166]. In addition, we can not rule out the spatial-coding view in certain circumstances such as the base-centred condition [44, 162]. Therefore, according to their study, we can not rule out the possibility for joint object-based correspondence effects of the grasping affordance account and the spatial coding account (i.e. object location) such that peripheral objects lead to even bigger correspondence effects [2, 44, 45, 162]. According to our experiment, the correspondence effect is the result of handle orientations and that of an afforded grasping action. However, item locations may also have an impact on correspondence effects [44]. Thus, the distribution of visual/spatial attention may be controlled by both item location as well as handle orientation [44]. Also, it is still possible that our object-based correspondence effects might involve an abstract spatial code (in response to item orientation) that modulates any discrimination for left or right responses [2, 44, 162, 165-167].

Furthermore, similarly to what is stated in Lien (2014), the fact that we used an object-centred condition allows a more sensitive and simpler assessment of the presence or absence of an affordance effect that is not very robust [35, 45]. This is explained by the fact that this condition involves a weaker spatial-coding effect (as opposed to the base-centred condition) which in turn has a lower tendency to obscure the affordance effect [35, 45]. That is, affordance effects could take place but are comparatively small i.e. when data involving spatial location is prominent (like in the base-centred condition), the robustness of the spatial-location effect eclipses the affordance effect making the affordance effect challenging to observe [35, 45]. On the other hand, in the absence of obvious spatial-location data, like in our object-centred condition, it might be simpler to observe an affordance effect [45]. However, although Lien (2014) state that this implies a slight potential for the affordance account, they do not conclusively support this interpretation [45, 167].

Does our semantic categorization task include parameters involved in the treatment of affordance?

Here, we will propose two distinct possibilities. Firstly, our semantic categorization/judgment task may involve the treatment of affordance i.e. the semantic decision may involve stimulus characteristics directly linked to grasping [35, 45]. Therefore, likewise to Tipper, our correspondence effect could be produced by the grasping part of the item and we could postulate that visual perception is altered by how much an item affords a precise action [36, 46]. In support of this option, we can postulate (like in other research) that: 1) attention is necessary to build the grasping affordance [1, 45] and 2) the task may necessitate the allocation of attention to an item feature pertinent to grasping [1, 35, 45, 164]. For example, decisions regarding whether an item is upright or inverted would involve properties considered to be pertinent to the grasping action and in turn, led to a slight correspondence effect where as colour decisions would involve properties considered to be non-pertinent to the grasping action and didn't lead to a correspondence effect [45, 164]. Also, our semantic categorization task might involve the semantic system which is associated with knowledge about object features like structure, function or size [62, 242].

Secondly, the alternative conclusion is that it does not necessarily take a task where attention is allocated to stimulus characteristics directly linked to grasping to generate the correspondence effects [35, 45]. In other words, we can oppose Tipper's idea that action affordances are only evoked when focusing attention on stimulus characteristics linked with grasping actions [35, 45].

For each distinct task, the attentional biases go to different regions of items

In Matheson (2014) (described in section 39), the notion that their categorization tasks (animal vs artifact) are made easier by attentional biases to the functional part of the artifacts does not fit with our results where the task is faster when the handle (not the functional part) is on the same side as the response hand [50]. However, the orientation judgment task (i.e. is the item upright or inverted) of Matheson (2014) likewise to our experiment are made easier by attentional biases towards artifact handles [50]. Thus, they state that their orientation judgments imply that attention is allocated to the manner in which the artifact can be handled in the motor sense. In contrast, their categorization task implies that attention is allocated to the artifact's function [50]. Hence, for our semantic categorization task, attention may be focused on the way in which the artifact can be handled from a motor point of view as opposed to its function [50]. The fact that the area of attentional bias for the artifact may differ between our categorization task and theirs could be explained by the fact that our categorization task involves only manipulable items (kitchen utensils and tools) where as their task contrast manipulable (artifacts) and non-manipulable (animal) stimuli with the latter only requiring identification (not handling) [50]. Although we only assessed the categorization task (kitchen utensils vs tools), we could suggest Matheson's assumption that for each task the attentional biases go to different areas of the items [50].

The on-line illustration of a displayed item involves action features

We could suggest that actions linked to our item are potentiated simply by the display of our item irrespective of whether acting on that item is possible (which is not the case since it is displayed on a screen) or part of the subject's goal (which is not the case since the goal is the categorization task) [62]. Thus, a portion of the on-line illustration of a displayed item involves action features [62]. Derbyshire (2006) also makes all the above postulations [62]. Hence, as proposed by Derbyshire (2006) and other studies, action features are similar to spatial or semantic features the illustration of which occurs during the item display irrespective of the subject's goals [62, 243-245]. Based on the time course of compatibility effects evaluated by Tucker and Ellis (2001) (section 19 of the review), our effects highlight the fact that action potentiation can be defined as on-line [11, 62]. That is, our compatibility effects (of object to action) and the action potentiation related to these effects are the temporary result of the item being simultaneously displayed [62].

Despite support for the on-line/dorsal route, there may be offline mechanisms

Based on previous studies, in our experiment (which involves overt movement and action), we could suggest (as postulated by TECs) activity in the dorsal action system during the visual presentation of the manipulable items [52, 30]. Indeed, it is likely that dorsal system processes play a role in our effects of item orientation (as in Tucker & Ellis, 1998) which is a feature of the item that relies on the viewpoint and this item feature has to be retrieved by a concurrently observed visual item in order to control action [5, 7]. In other words, based on Tucker (2004), it is necessary that item attributes which rely on the vantage point (such as our orientation attribute) must be evaluated on-line since this information can be modified continuously when the subject or the target moves [7]. In turn, we could potentially support the mechanism involving the on-line or dorsal route for extracting affordances (described in section 19 of the review) [7, 11]. Likewise to what is postulated in Tucker (2004), our correspondence effects on the hand responses are most likely evoked by the spatial information that is transiently associated to the items we displayed [7, 246, 247]. However, in our experiment discussed here, we did not assess the effects when subjects respond after the offset of the item but in regards to our arrow and dot experiments (which will be discussed later) we do assess responses that take place following the item offset [7, 11].

However, some conclusions of Tucker (2004) (described in section 19 of the review) oppose earlier studies that stress the importance of the dorsal system processes in affordance effects [5, 7, 11]. Indeed, it is possible for the observer to retain some spatial information off-line [7]. Such conclusions would make the most sense for intrinsic item features (such as the grip type they assessed) and their associations with action affordances [7]. The findings from Tucker (2004) (regarding grip type) support the notion that item affordance effects in off-line methodologies are indicative of the activation of stored action knowledge which is based on previous interactions that have become part of the item illustration itself [7, 21, 246]. Such action knowledge is solely roughly tuned and is indicative of groups of roughly defined actions rather than the specifically tuned adjustments that take place during actual actions [7]. In contrast, the link between extrinsic item features (like our orientation attribute) and actions would be influenced more significantly by direct visual input [7]. Nevertheless, in our experiment, we can not rule out the involvement of this stored action knowledge [7, 21, 246]. For example, it is possible that items with an orientation generate general categories of actions which are founded on previous interactions in alike orientations [5, 7]. In fact, regarding the generation of compatibility effects in bimanual experiments (like ours), action categories may be generally outlined as a favoured hand [5, 7].

<u>Addressing the fact that we employed keypress responses as opposed to real gripping responses</u>

Lien (2013) and other authors go against the conclusions found by Goslin (2012) and our experiment. Bub and Masson (2010) state that the illustrations (linked with the gripping of the item's handle) can lead to some object-based correspondence effects when there are real gripping responses [2, 44, 165]. However, as opposed to our results, they do not make the same conclusions regarding correspondence effects when there are keypress responses [2, 44, 165]. In the Lien and

Goslin studies as well as our experiment, the subject's goal was to make a left or right keypress response as opposed to grasping the images of items displayed on the screen [2, 44, 61]. Bub and Masson (2010) did not demonstrate object-based correspondence effects in an experiment that employed keypresses but we did [44, 165]. In turn, they propose that the treatment of item features linked to grasping is not necessarily primed by these goals of executing keypress responses but our findings show that it can be [44, 165]. They explain that such responses are too unrelated to any action associated with an object [44, 165]. Hence, according to them, the keypress cannot lead to motor illustrations that give an advantage for a response by one hand rather than the other but our findings show that this is a possibility [44, 165]. Also, they state that the action of descending the finger upon a key is very different from the mechanism of moving the hand through space to a specific location and shaping it to grasp the target [44, 165]. However, our effect occurs as though the participant is in fact attempting to grasp the handle [5, 45]. Lien (2013) does not preclude the fact that a subject's goal plays a role in the treatment of information but they point out that keypress responses are mostly coded by spatial location [44, 59]. Based on their behavioral and electrophysiological findings, they explain that, similarly to different spatial compatibility effects, it is the overlap between the spatial codes for stimuli and the spatial codes for responses that leads to the automatic processing of items in keypress tasks (which gives way to correspondence effects) [44, 60]. In contrast, our findings could still support an affordance account with keypress responses (as opposed to their spatial-coding account) [44]. In fact, our experiment and previous research have shown that: 1) action selection is directly impacted by visual information such as the visual attributes of items and 2) this was shown without real actions actually being executed (since our subjects make keypress responses as opposed to actual actions towards the objects) [159, 197].

<u>How does our experiment fit with the dual route notion: the direct visual path vs the semantic path?</u>
In the review (section 44), we go over Yoon (2007) that contrast the direct visual path to action and the semantic path by comparing the impact on an action decision task vs a semantic categorization task by two factors: viewpoint vs semantic priming, respectively [159]. In our experiment, we could support this dual route notion for action selection [68, 159, 210]. In other words, it is possible that there are two separate routes to action (with a distinct nature): the semantic route (from semantic knowledge to action) and 2) the direct visual route to action (from vision to action) [159, 248, 249]. However, our experiment could indicate that these separate routes are not

entirely independent and could impact one another. As explained in section 44, studies demonstrated that viewpoint/ orientation impacts action decisions (which relies on the direct visual path to action) but not semantic (contextual) judgements tasks [193, 159]. In other words, information about viewpoint plays an important role in the regulation of online action (i.e. the direct visual path to action) but has a weaker impact on item recognition (i.e. the semantic path) which, in contrast to action, does not vary with distinct viewpoints [250, 159, 201, 251-253]. Our results (although we used a semantic categorization task and not an action decision task) mirror the results described in section 44 i.e. the RTs were shorter for congruent trials where the orientation of the item's graspable part is towards the response hand as opposed to away (although we did not find this effect for PEs) [159]. Thus, our task was impacted by viewpoint/orientation and the modifications in viewpoint are sufficiently robust to impact the RTs of our semantic judgments [159, 201]. Therefore, we could propose that our semantic categorization task would involve the semantic route where as the non-semantical activation of an action affordance by our displayed object would involve the direct visual route to action (i.e. vision influences action directly) [69, 193, 159, 254, 255]. In other words, similarly to the conclusions made by Yoon (2010), we could suggest that the visual path to action depends on the items' affordances [12, 193]. Hence, although we could accept Yoon's assumption (supported by neuropsychological studies) that the direct path to action could be more impacted by the viewpoint/orientation of the item (with respect to the effector utilized in performing the action) than the semantic/item recognition path, our results show that the latter path is also somehow impacted by viewpoint [159, 256, 248, 249]. In turn, we could suggest that, in our experiment, even if the two routes were separate, the direct visual route to action can impact the semantic route [69, 159]. Thus, it is possible that viewpoint does not strongly impact the semantic path directly but viewpoint may impact the direct visual route to action which in turn impacts the semantic route [159]. This hypothesis would imply an added characteristic to the dual route model of previous research [68, 193, 159, 210]. The impact of the direct path to action on the semantic path is consistent with earlier studies that demonstrated that harm to the visual path can influence the utilization of the semantic path to action [159, 210]. In turn, we can support the convergent route model proposed by Yoon, Heinke and Humphreys (2002) and defined in section 44 [159, 210]. Also, we could not completely support the double dissociation mentioned in Yoon (2007) (section 44) i.e. the routes to semantic knowledge and to action may not be entirely independent for objects [69, 159, 195]. Thus, our effects may involve a combination of access to semantic knowledge and action knowledge [193, 159].

According to this hypothesis, we can make a similar assumption to that made by Yoon that modifications in viewpoint did not obscure significant elements of objects utilized in their identification [159]. Thus, as in earlier research (section 44), the rotations of our items (in regards to their orientation/viewpoint) may not strongly and directly impact access to semantic information or knowledge since the important elements of items could be seen [159, 201]. Also, based on some studies (section 44), we could suggest that vision led to an advantaged accessibility to action knowledge due to learnt connections of items with actions [159, 197].

Our experiment supports a direct path from vision to action

Based on Yoon (2007) and previous neuropsychological studies, we could suggest that our direct interaction between visual object information and action selection and control takes place online [159]. That is, according to previous research, this would involve the direct path to action [159, 248, 249]. Therefore, we can potentially make the same conclusion as previous research regarding the grasp action afforded by items: grasping depends on the direct link between the visual item attributes and the effector systems and priming would not have any impact on this link [159, 257, 258]. Also, according to some research, one characteristic of this direct path is that there would be a fast decline of activation of visually guided action when the display of the stimulus and the following action are separated by a time interval [159-161]. In our experiment in question here, we did not assess such time intervals but we did in our subsequent (arrow and dot) experiments.

Some advantages to our experiment

Here, we will discuss some advantages to our experiment. Based on previous findings, the fact that we utilized images of common actual objects could have given way to a more effective categorization [181, 259]. In addition, we minimize the continuous state of flux since our items on the screen do not move, are not moved and are only observed by one viewpoint [181]. In turn, this facilitates the learning of the illustration of the surrounding (i.e. the displayed item) [181]. Furthermore, one advantage is that we employed several distinct objects as stimuli instead of , for example, just one door-handle object (employed in the studies by Tipper, Cho and Proctor and Lien) [35, 45, 162, 167] or other earlier research (e.g., Cho & Proctor, 2010; Phillips & Ward, 2002)[25, 166] which employed a restricted amount of poor, schematic stimuli (for instance, only frying pans) [50]. Such stimuli could make it problematic to assess if the effects in a categorization task are caused by the category of the items itself or by another low-level stimulus component of the specific picture employed [50]. In addition, employing only one kind of stimulus prevents the results of these studies from being widespread since reiteration of that one stimulus can lead to a rise in the treatment of specific item components [50, 260]. Furthermore, practice with precise mixtures of stimuli and responses can lead to a reduction in the SRC effects [50, 313]. Hence, in earlier studies, it is unknown if employing only one stimulus could bias mechanisms involving vision or attention [50]. The fact that we utilized many kinds of stimuli precludes these limitations. Likewise to our experiment, Matheson (2014), employed a big set of stimuli that are intricate in terms of vision in order to allow the results to be generalized [50]. Also, we only utilized non-living manmade items precluding confounds involving living or non-living items and natural or manmade items [52, 262]. Moreover, as opposed to studies like Yoon (2007), the action affordances are not limited by our experimental design to isolated actions (such as only twisting) i.e. all kinds of action affordances can impact task performance [159].

The advantages of a categorization task

Here, we will go over the advantages of employing our categorization task (which are mentioned in Matheson (2014)) [50, 164]. For one, the subject's choice is kept binary and the overt treatment of item features is still necessary (in contrast to other experiments where subjects must focus on other non-pertinent components of the item such as in a dot discrimination task which leads to the disappearance of the potentiation effect) [1, 50]. In addition, the categorization task is different than the color task by Vainio, Ellis and Tucker (2007) where subjects reply to the color alteration of a dot and not to a feature of the item [1, 50]. In turn, Matheson explains that a categorization task allows them to analyse the potentiation effect when the subject's attention is allocated to both their item categories (artifacts and animals) as in our experiment (for kitchen utensils and tools) [50]. Also, a categorization task in contrast to an identification task depends on distinct neural processes [50, 238]. Studies employing fMRI showed that fronto-parietal networks implicated in treating manipulable items are more robustly activated during a categorization task than an identification task [50, 238]. Matheson proposes that there would be a stronger potentiation effect for artifacts in a categorization task (compared to an identification task) since this procedure should include fronto-parietal systems involved in the formation of action [50, 238].

Some limitations to our experiment

Here, we will discuss limitations to our experiment. In contrast to studies by Goslin and Lien, our experiment has a smaller sample size and a smaller number of trials [2, 44]. Moreover, as in earlier experiments, we lack an efficient control for the impact of experience (such as familiarity or age of acquisition i.e. the age when subjects include an item name in their vocabulary) with distinct categories of items [52, 234, 263]. Also, we only used a single experimental block (apart from the practice block, the results of which were not taken into account). Hence, a limitation is that we could not assess the impacts of practice or exposure to stimuli [52]. Once again, another limitation may be that we only utilized manipulable items and not non-manipulable items [52]. For example, Salmon (2014) demonstrated that item processing is influenced by item manipulability [52]. Moreover, although Salmon (2014) employed a control of the most relevant confounding factors, they point out that item processing is still affected by various other factors (for items from the real world) like : 1) colour [264, 265], 2) quality of the image [266], 3) size [267], and 4) item orientation [268] [52]. In turn, all these factors may have affected our item processing although we are aware that item orientation plays an important role in our experiment by design [52]. Finally, the lack of consideration for hand dominance may be a limitation to this experiment but should not influence most of our interpretations (as explained in section 45 of my review). However, the hand dominance effect could a play a role in the differences between the two categories of objects (kitchen utensils vs tools) and the orientation by category interaction.

VIII. EXPERIMENT 3: arrow experiment

INTRODUCTION

As in Goslin and Tucker and Ellis (1998), our behavioral findings for Experiment 2 supported the notion that there was a lateralized affordance effect [2, 5] i.e. there was a facilitation of action when there was congruency between the item’s graspable part and the envisioned hand of response [2, 5]. This implied that when the side by which an object was grasped (such as its handle) corresponded to the same side (i.e. left hand or right hand) with which the subject responded during the categorization task, there was a facilitation effect caused by affordance [2]. On the other hand, when both sides were opposite to one another, there was an inhibition effect caused by affordance [2]. The facilitation was depicted by the shorter average RT for keypress responses in congruent trials compared to the average RT for incongruent trials [2, 5]. Therefore, Experiment 2 showed the existence of affordances but to assess the temporal features, we needed to introduce SOAs in the “arrow experiment”. The goal of this “arrow experiment” was to look at the results in terms of these temporal features and, more importantly, to assess the activation and inhibition of affordances. We call this the “arrow experiment” because the target in regards to which the subject must respond was an arrow presented at the center of the screen.

METHOD

Participants:

We asked 36 subjects to participate in the experiment. However, as will be explained below, we excluded the results for 2 of the subjects leaving 34 subjects. All subjects were asked to sign an informed consent form approved by the Research Ethic Board of the Douglas Institute. Two out of the 34 subjects were left-handed. The age spanned from 18 years old to 45 years old. The average age was 24.3 ± 5.8 years old. The subjects consisted of 22 females and 12 males. Furthermore, all subjects said they have normal or corrected to- normal visual acuity.

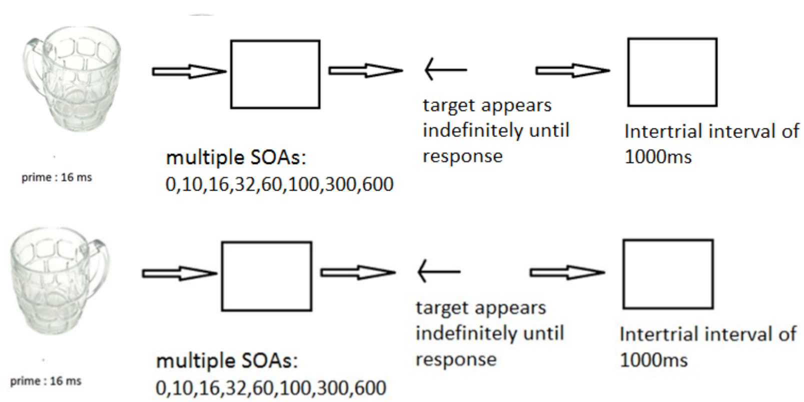
Stimuli and procedure:

We selected 32 object image stimuli according to the results of Experiment 1 i.e. selection of stimuli. We selected objects for which there was a total consensus as to which hand to use to grasp the object in Experiment 1. This experiment started with an image of an object that can be grasped with the left or right hand. This image appeared for 16 ms. Afterwards, there was an interval consisting of a blank screen. There were 8 blocks which each had a distinct SOA for the blank screen duration. Hence, this time interval varied for each of the 8 blocks (0 ms, 10 ms, 16 ms, 32 ms, 60 ms, 100 ms, 300 ms and 600 ms). This blank screen was then followed by an image of a central arrow that either pointed to the right or to the left. We told the participants to respond to an arrow pointing to the right by pressing the letter “m” on the keyboard with their right hand and to respond to an arrow pointing to the left by pressing the letter “z” on the keyboard with their left hand. The images of objects were task-irrelevant and, thus, were not mentioned in the instructions given to participants. The images of arrows appeared indefinitely until the subject responds. Once the subject responds, a blank screen appeared as an inter-trial interval for 1000 ms. After this inter-trial interval, the next trial began (i.e. the image of another object appeared on the screen). Participants were told to focus on the center of the screen throughout the whole experiment and to respond to the arrows as quickly and as accurately as possible. Each block consisted of the same

32 different stimuli i.e. 32 different images of objects (there were no mirror images of the same object). Half of the 32 stimuli could be grasped with the right hand and the other half could be grasped with the left hand. Also, in half of the 32 trials, the arrow pointed to the right and, in the other half, the arrow pointed to the left. In addition, half of the trials were compatible i.e. the hand with which one would grasp the object was on the same side as the direction of the arrow. For example, in a compatible trial, one would grasp the object with the right hand and the following arrow would point to the right. The other half of the 32 trials were incompatible i.e. the hand with which one would grasp the object was on the opposite side to the direction of the arrow. For example, in an incompatible trial, one would grasp the object with the right hand but the following arrow would point to the left.

Subjects sat in a dimly-lit room about 50 cm from the computer screen. The images of objects and the images of arrows were located at the center of the screen. We put all the images in a design using the e-prime program. In this e-prime experiment, the trials appeared in a random order for each block. In addition, the order of the blocks was also selected randomly. We looked at both the reaction times to respond to the arrows and the error rates in responding to the arrows. In the e-prime sequence, in order to start the experiment for each block, the subject had to press the space bar. Subjects were told to respond as quickly and as accurately as possible.

Figure 8.1. *An example of a compatible trial (top) and an incompatible trial (bottom)*



DATA ANALYSES

Firstly, for each of the 36 subjects, we calculated the sum of errors across the 8 blocks. We then averaged the sums across all subjects and found an average of 7.9 (± 8.0). We added 2 SDs to the average which leads to 23.9. In turn, we excluded all subjects that had a sum of errors greater than 23.9 i.e. we removed two subjects with 26 errors and 38 errors. This left us with 34 subjects.

As in Experiment 2, for the assessments of the results, we averaged the RTs that remained after the exclusion of the first trial, the incorrect responses and the 2 SDs above or below the mean. Also, we calculated the amount of errors.

In terms of RTs and error rates, we calculated a repeated measures ANOVA with 3 factors: SOA (8 blocks: 0ms, 10 ms, 16 ms, 32 ms, 60 ms, 100 ms, 300 ms and 600 ms) X compatibility (compatible vs incompatible) x laterality (arrow pointing to the right or arrow pointing to the left). All the following statistics are a Huynh-Feldt statistic given that we can't assume sphericity.

RESULTS

In terms of RTs, the 3-way interaction of SOA, compatibility and laterality was not significant $F(7, 231) = 1.095$, $p = 0.363$. The 2- way interaction of SOA and compatibility was significant $F(7, 231) = 3.692$, $p = .002$. The main effect of SOA was significant, $F(7,231) = 11.275$, $p < 0.001$. The main effect of compatibility was significant $F(1, 33) = 129.484$, $p < 0.001$.

In terms of RTs, because of the significant two-way interaction, we then tested ANOVAs with 2 factors: SOA (for each 2 subsequent blocks) and compatibility (compatible vs incompatible). The statistical results are in the following table.

Table 8.1. *ANOVAs results with 2 factors: SOA and compatibility (in terms of RTs)*

SOAs	SOAXcompatibility	SOA	compatibility
0ms vs 10ms	F (1, 33) = 0.851, p=0.363	F (1, 33) = 0.064, p= 0.801	F (1, 33) = 71.229, p< 0.001
10ms vs 16ms	F (1, 33) = 0.281, p=0.600	F (1, 33) = .821, p= .372	F (1, 33) = 54.173, p< 0.001
16ms vs 32ms	F (1, 33) = .623, p=.436	F (1, 33) = 1.472, p= .234	F (1, 33) = 44.321, p< 0.001
32ms vs 60ms	F (1, 33) = 3.285, p=.079	F (1, 33) = 1.699, p= .201	F (1, 33) = 31.623, p< 0.001
60ms vs 100ms	F (1, 33) = 2.336, p=.136	F (1, 33) = 2.449, p= .127	F (1, 33) = 30.765, p< 0.001
100ms vs 300 ms	F (1, 33) = 3.016, p=.092	F (1, 33) = 11.695, p= .002	F (1, 33) = 40.128, p< 0.001
300ms vs 600 ms	F (1, 33) = 1.654, p=.207	F (1, 33) = .249, p= .621	F (1, 33) = 16.986, p< 0.001

We calculated a paired samples t-test for RTs comparing compatible trials to incompatible trials for each SOA. For all SOAs, the comparison was significant with a p-value below or equal to 0.004 ($t(33) > 3.120$) except the 600 ms SOA (although also significant) which had a p-value of 0.020, $t(33) = 2.437$. In addition, for all SOAs, the t-value is positive.

For error rates, the 3-way interaction of SOA, compatibility and laterality was not significant $F(7, 231) = .305$, $p = .921$. The 2- way interaction of SOA and compatibility was significant $F(7, 231) = 2.238$, $p = .036$. The main effect of SOA was significant, $F(7,231) = 2.341$, $p = .030$. The main effect of compatibility was significant $F(1, 33) = 32.071$, $p < 0.001$.

In terms of error rates, because of the significant two-way interaction, we then tested

ANOVAs with 2 factors: SOA (for each 2 subsequent blocks) and compatibility (compatible vs incompatible). The statistical results are in the following table.

Table 8.2. *ANOVAs results with 2 factors: SOA and compatibility (in terms of error rates)*

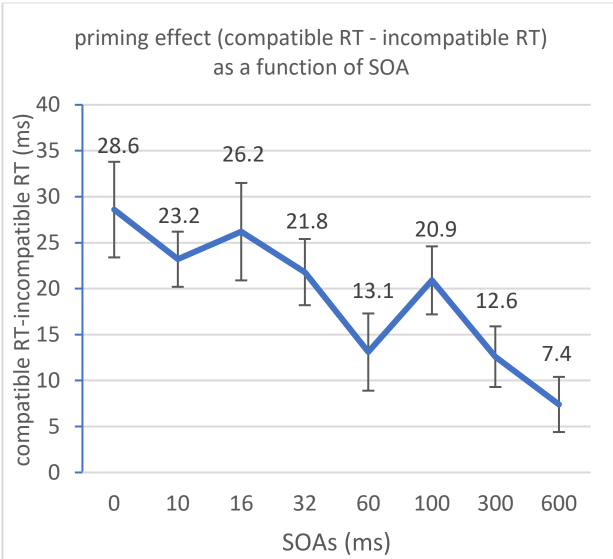
SOAs	SOAXcompatibility	SOA	compatibility
0ms vs 10ms	F (1, 33) = 1.845, p=.184	F (1, 33) = 1.337, p= .256	F (1, 33) = 15.618, p< 0.001
10ms vs 16ms	F (1, 33) = .946, p=.338	F (1, 33) = 1.061, p= .311	F (1, 33) = 14.227, p= .001
16ms vs 32ms	F (1, 33) = .026, p=.872	F (1, 33) = .029, p= 0.865	F (1, 33) = 18.553, p< 0.001
32ms vs 60ms	F (1, 33) = .777, p= .384	F (1, 33) = 2.809, p= .103	F (1, 33) = 18.723, p< 0.001
60ms vs 100ms	F (1, 33) = .573, p=.454	F (1, 33) = .314, p= .579	F (1, 33) = 15.696, p< 0.001
100ms vs 300 ms	F (1, 33) = 4.514, p=.041	F (1, 33) = 3.873, p= .058	F (1, 33) = 6.689, p= .014
300ms vs 600 ms	F (1, 33) = .304, p=.585	F (1, 33) = 1.092, p= .304	F (1, 33) = 1.507, p= .228

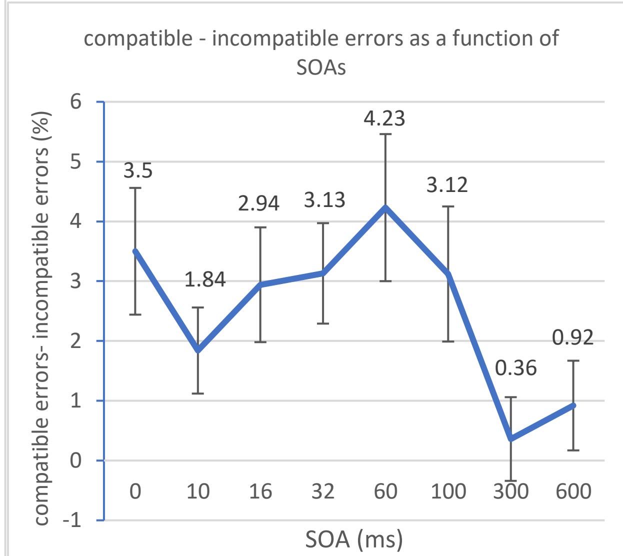
We calculated a paired samples t-test for error rates comparing compatible trials to incompatible trials for each SOA. For the 0ms to the 100 ms SOAs, the comparison was significant with a p-value below or equal to 0.016 ($t(33) > 2.539$) where as for the 300 ms and 600 ms SOAs, the comparison was not significant, $t(33)= .529$, $p= .600$ and $t(33)= 1.221$, $p= .231$, respectively. For all SOAs, the t-value is positive.

SOA	RT/error rate	compatible trials	incompatible trials
0ms	mean RT	421.3 ms ± 57.0	392.7ms ± 46.8
	mean error rate	5.15 % ± 5.65 %	1.65 % ± 3.19 %
10ms	mean RT	417.4 ms ± 49.1	394.2 ms ± 52.4
	mean error rate	3.68 % ± 4.10 %	1.84 % ± 3.27 %
16ms	mean RT	432.2 ms ± 101.2	406.0 ms ± 81.9
	mean error rate	3.68 % ± 5.13 %	0.74 % ± 2.04 %
32ms	mean RT	414.7 ms ± 50.0	392.9 ms ± 47.8
	mean error rate	3.68 % ± 5.36 %	0.55 % ± 1.80 %
60 ms	mean RT	399.9 ms ± 56.7	386.8 ms ± 69.1
	mean error rate	5.33 % ± 7.24 %	1.10 % ± 2.42 %
100 ms	mean RT	392.4 ms ± 44.0	371.5 ms ± 48.0
	mean error rate	4.41 % ± 6.26 %	1.29 % ± 2.57 %
300 ms	mean RT	366.6 ms ± 50.7	354.0 ms ± 50.0
	mean error rate	1.65 % ± 3.55 %	1.29 % ± 2.57 %
600 ms	mean RT	366.8 ms ± 50.5	359.4 ms ± 45.8
	mean error rate	2.57 % ± 3.48 %	1.65 % ± 3.19%

Table 8.3. *In the table to the left, we present the mean RTs for compatible and incompatible trials as well as the mean error rates for compatible and incompatible trials.*

Figure 8.2. and ***Figure 8.3.*** *For the following figures, we show the mean of the difference between compatible and incompatible trials for RTs and error rates (with the standard error) for each SOA.*





IX. EXPERIMENT 4: dot experiment

INTRODUCTION

Similarly to the "arrow experiment", the goal of this "dot experiment" is also to evaluate the findings in regards to the temporal features of the affordance effect and, of greater pertinence, to examine the affordance activation and inhibition. However, as opposed to the "arrow experiment", the target towards which the subject has to respond is in this case a dot presented peripherally to the left or right of the screen.

METHOD

Participants:

Seventy-eight participants took part in the experiment. Yet, as will be clarified later on, we rejected the results for 4 of the participants which left us with 74 subjects. All participants had to sign an informed consent form approved by the Research Ethic Board of the Douglas Institute. Eight out of the 74 participants were left-handed. The participants were 18 years old to 66 years old. The mean age was 25.7 ± 8.6 years old. The participants included 50 females and 24 males. In addition, all participants reported normal or corrected to- normal visual acuity.

Stimuli and procedure:

Based on the findings of Experiment 1 which involves stimuli selection, we chose 32 object picture stimuli. We chose objects for which all subjects in Experiment 1 agreed as to which hand they would employ for grasping the object. This "dot experiment" began with a picture of an object which is graspable with the left or right hand. This picture was displayed for 16 ms. Subsequently, there was a blank screen displayed for a certain time interval. This time interval was altered throughout 8 blocks (0 ms, 10 ms, 16 ms, 32 ms, 60 ms, 100 ms, 300 ms and 600 ms). This blank screen occurred prior to a lateralized dot located to the right or to the left of the screen. We instructed subjects to respond to a dot located at the right of the screen by making a keypress with their right hand on the letter "m" of the keyboard and to respond to a dot located at the left of the screen by making a keypress with their left hand on the letter "z" of the keyboard. The pictures of objects were not relevant to the task and, hence, were not stated in the instructions the subjects received. The images of dots stayed displayed without a time limit up to the response by the participants. Following this response, a blank screen took place for a duration of 1000 ms serving as an inter-trial interval. Following this inter-trial interval, the subsequent trial started: the picture of a different object was displayed on the screen. Subjects were instructed to focus on the screen's center across the entire experiment and to respond to the dots as fast and as accurately as possible. Every block comprised the identical 32 distinct stimuli i.e. 32 distinct pictures of objects. We did not employ mirror images of the same object. One half of the 32 stimuli (i.e. 16 stimuli) was graspable with the right hand and the second half was graspable with the left hand. In addition, in one half of the 32 trials, the dot was located at the right of the screen where as, in the second half, the dot was located at the left of the screen. Furthermore, for one half of the trials, the hand employed to grasp the object was on the identical side to the dot location (compatible trials). For instance, in a compatible trial, the subject would use the right hand to grasp the object and the subsequent dot would be located to the right of the screen. For the second half of the 32 trials, the hand employed to grasp the object was on the reverse side to the dot location (incompatible trials). For instance, in an incompatible trial, the subject would use the right hand to grasp the object but the subsequent dot would be located at the left of the screen.

Subjects were seated in a dimly-lit room around 50 cm from the screen of the computer. The pictures of objects were positioned at the screen's center and the images of dots were lateralized to the left or to the right of the screen. We included all the pictures in a design employing the e-prime program. In this e-prime experiment, the trials occur in a random manner for every block. Furthermore, the blocks' orders were also chosen in a random manner. We assessed both the reaction times for responses to the dots and the error rates of those responses.

In the e-prime program, the participant was told to press the space bar to begin the experiment for every block. Participants were instructed to respond as fast and as accurately as possible.

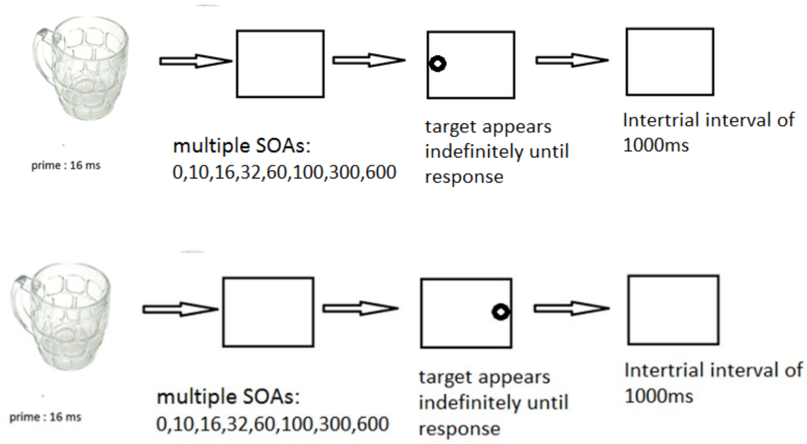


Figure 9.1. *An example of a compatible trial (top) and an incompatible trial (bottom)*

DATA ANALYSES

For every subject (out of the 78 subjects), we assessed the sum of errors throughout the 8 blocks. We then calculated a mean of the sums throughout all subjects which was 4.8 (± 4.3). We added 2 SDs to the mean which gave a result of 13.4. Subsequently, we rejected every participant with a sum of errors above 13.4: we rejected four participants with 14 errors, 14 errors, 14 errors and 18 errors. In turn, there remained 74 subjects. Similarly to the Experiment 2, for the evaluation of the results, we looked at the RTs that were left following the rejection of the first trial, the incorrect responses and the RTs outside 2 SDs from the mean. In addition, we looked at error rates.

In regards to RTs and error rates, we assessed a repeated measures ANOVA with 3 factors: SOA (8 blocks: 0ms, 10 ms, 16 ms, 32 ms, 60 ms, 100 ms, 300 ms and 600 ms) X compatibility (compatible vs incompatible) x laterality (dot located to the right or to the left of the screen). All the subsequent statistics are a Huynh-Feldt statistic since we can't assume sphericity.

RESULTS

In regards to RTs, the SOA /compatibility/ laterality 3-way interaction was not significant $F(7, 511) = 1.623$, $p = 0.127$. The SOA/ compatibility 2- way interaction is significant $F(7, 511) = 2.514$, $p = 0.019$. The SOA main effect is significant, $F(7,511) = 15.022$, $p < 0.001$. The compatibility main effect is not significant $F(1, 73) = 1.029$, $p = .314$.

In regards to RTs, since the two-way interaction was significant, we assessed ANOVAs with 2 factors: SOA (for every 2 successive blocks) and compatibility (compatible vs incompatible). The statistical findings are presented in the table below.

Table 9.1. *ANOVAs results with 2 factors: SOA and compatibility (in terms of RTs)*

SOAs	SOAXcompatibility	SOA	compatibility
0ms vs 10ms	F (1, 73) = 0.606, p=0.439	F (1, 73) = 4.390, p= .040	F (1, 73) = 0.151, p= 0.699
10ms vs 16ms	F (1,73) = .059, p=.808	F (1, 73) = 7.422, p= .008	F (1, 73) = .955, p= .332
16ms vs 32ms	F (1, 73) = .246, p=.622	F (1, 73) = 2.223, p= .140	F (1, 73) = 1.161, p= .285
32ms vs 60ms	F (1, 73) = 4.938, p=.029	F (1, 73) = 9.830, p= .002	F (1, 73) = .539, p= .465
60ms vs 100ms	F (1, 73) = 1.282, p=.261	F (1, 73) = .589, p= .445	F (1, 73) = 11.931, p= .001
100ms vs 300 ms	F (1, 73) = 6.555, p=.013	F (1, 73) = 5.883, p= .018	F (1, 73) = 5.458, p= .022
300ms vs 600 ms	F (1, 73) = .129, p=.721	F (1, 73) = .116, p= .734	F (1, 73) = .051, p= .823

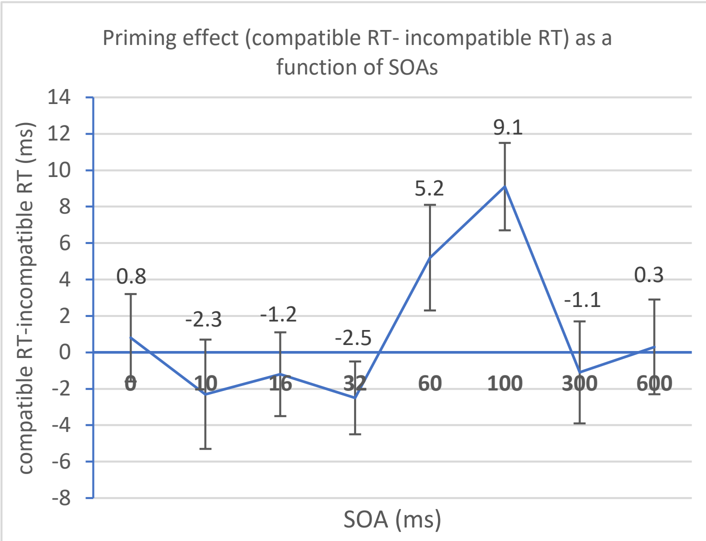
We assessed a paired samples t-test for every SOA contrasting compatible trials with incompatible trials. For 0ms, the difference between compatible trials and incompatible trials is not statistically significant and the t-value is positive t(73) = .314, p= .755. For the 10ms to 32 ms SOAs, the difference between compatible trials and incompatible trials is not statistically significant and the t-value is negative (for 10 ms: t(73)= -.746, p= .458; for 16 ms: t(73)= -.557, p= .579; for 32 ms: t(73)= -1.247, p= .216).

For the 60 ms SOA, the difference between compatible trials and incompatible trials is not statistically significant and the t-value is positive, t(73) = 1.786, p= .078. For the 100 ms SOA, the difference between compatible trials and incompatible trials is statistically significant and the t-value is positive, t(73) = 3.696, p< 0.001. For the 300 ms SOA, the difference between compatible trials and incompatible trials is not statistically significant and the t-value is negative, t(73) = -.398, p= .692. For the 600 ms SOA, the difference between compatible trials and incompatible trials is not statistically significant and the t-value is positive, t(73) = .098, p= .922.

SOA	compatible trials	incompatible trials
0 ms	343.2 ms ± 41.2	342.4 ms ± 48.6
10 ms	358.1 ms ± 86.5	360.4 ms ± 86.9
16 ms	338.7 ms ± 39.5	339.9 ms ± 40.9
32 ms	333.5 ms ± 40.1	336.0 ms ± 41.7
60 ms	326.6 ms ± 45.5	321.4 ms ± 40.1
100 ms	331.7 ms ± 57.3	322.6 ms ± 52.0
300 ms	315.1 ms ± 49.8	316.2 ms ± 62.0
600 ms	317.6 ms ± 39.3	317.3 ms ± 39.3

Table 9.2. *Average RTs for compatible and incompatible trials.*

Figure 9.2. *The mean of the difference between compatible and incompatible trials for RTs (with the standard error) for each SOA.*



In terms of error rates, we calculated a repeated measures ANOVA with 3 factors: SOA (8 blocks: 0ms, 10 ms, 16 ms, 32 ms, 60 ms, 100 ms, 300 ms and 600 ms) X compatibility (compatible vs incompatible) x laterality (dots located to the left or right of the screen). All the following statistics are a Huynh-Feldt statistic given that we can't assume sphericity.

In terms of error rates, the SOA/ compatibility/ laterality 3-way interaction was not significant F (7, 511) = 1.076, p= .375. The SOA X compatibility 2- way interaction is not significant F (7, 511) =.605, p= .708. The SOA main effect is significant, F (7,511) = 8.268, p< 0.001. The compatibility main effect is not significant F (1, 73) =3.441, p= .068.

Since the 2-way interaction and the compatibility main effect are not significant, we can not calculate additional statistics in regards to error rates.

X. EXPERIMENT 3 and 4 (arrow and dot experiments): DISCUSSION

Our findings in general

Here, we give an overview of our results. In our arrow experiment, the incompatible trials imply that the orientation of the prime object -in regards to whether the left or right hand would be used to grasp it – and the direction the target arrow is pointing towards, are opposite to one another. In contrast, the compatible trials imply that the prime object orientation and the target arrow direction are on the same side. The NCE is indicative of shorter RTs and lower error rates for incompatible trials compared to compatible trials. In our arrow experiment for RTs, we observe NCEs at all SOAs (i.e. time intervals between prime and target) between 0ms and 600ms. However, the NCE seems to decrease with increasing SOA and we can postulate that beyond the 600 ms SOA (the longest SOA we assessed), the NCE may potentially turn into a PCE.

When we looked at error rates, we subtract the average error rate for incompatible trials from the average error rate for compatible trials. For all SOAs (except 300 and 600 ms), there are significantly higher error rates for compatible trials compared to incompatible trials which fits with the RT results and the NCE. The curve of compatibility errors – incompatibility errors as a function of SOA is in an inverted U-shape and towards the longer SOA, it involves a steep decrease. More specifically, in the arrow experiment, for both RT and error rate, there is a trend towards a decrease in the NCE with increasing SOA. However, for the error rate, the decrease in NCE is steep and restricted to the longer SOAS. What explains error rates may not exactly be the same as the logic for RTs in terms of the arrow experiment so the mechanisms leading to error rates may not be exactly the same as those related to RTs. It may be difficult to explain the mechanisms leading to our results in terms of error rate. In addition, in our arrow experiment, we did not observe a trade off between the rapidity of the response and its accuracy.

In the dot experiment, the compatible trials imply that the prime object orientation and the target dot are on the same side where as the incompatible trials imply that they are on opposite sides. A PCE implies shorter RTs and lower error rates for compatible compared to incompatible trials where as an NCE implies the opposite. In this experiment, there is a potential PCE trend at short SOAs (indicative of potential facilitation and potentially the activation of affordance). Yet, at short SOAs, this PCE trend is not statistically significant as there is a lack of significant compatibility effects. In contrast, at long SOAs, there is a clear NCE (indicative of inhibition). This NCE effect faded away by the 300 ms and 600 ms SOAs. In this experiment, in terms of error rates, there was no significant interaction between SOA and compatibility and no significant main effect of compatibility. The logic of our results for both our experiments will be addressed in this discussion.

<u>Our findings fit with motor simulations and the affordance account: the basic conclusions</u>

As supported by earlier studies, we demonstrate that merely looking at common graspable items that are usually used in specific ways evokes in an automatic manner motor simulation for using those items [28]. Our findings propose that the orientation of a tool produces an action plan for grasping the tool with the hand that is closest to the tool (this is also supported by other studies) [5, 28]. In other words, our experiments assessed an item's orientation in terms of the best suited hand to make a reach-and-grasp action [5]. This was also carried out in the first experiment of Tucker and Ellis (1998) (with some differences in the methodology) [5]. In addition, we show that the leftward or rightward orientation of our items has an impact on the task performance which involves the left or right hands [5, 25, 29, 34, 35]. This was demonstrated in many studies when an item has to be categorized [5, 25, 29, 34, 35]. In other words, our experiments demonstrated that the handle (or graspable part) affordance of an observed item (i.e. the prime object) automatically affects the mechanisms involving the choice of a response [25, 26, 35, 269]. Many studies employing a SRC paradigm also back up this conclusion [25, 26, 35, 269]. Our handle-affordance effect implies that the handle affordance of the observed item generates a rapid automatic activation of an action illustration linked with the hand most appropriate for the item grasp (this concept is also supported by other studies) [1, 5, 26, 29, 48]. Thus, in our experiments, given that the illustration of a visual item involves action attributes, such as the favored activation of the hand best suited to perform a reach-and-grasp action, then it is expected that this activation would facilitate trivial keypress responses executed by the congruent hand and, on the other hand, to deter those same responses executed by the incongruent hand (this postulation is supported by Tucker and Ellis (1998)) [5]. More specifically, this concept applies to our potential PCE trend (although it is not statistically significant in the dot experiment or observed in the arrow experiment even though it could be expected at longer SOAs than 600ms): the completion of the task would take less time when there was congruency between response hand and prime item orientation despite the orientation being irrelevant to the task (other studies also support this conclusion) [5, 25, 29, 34, 35]. Also, certain studies support the fact that motor simulation (which we think is evoked by our prime objects) and actual motor performance (which does not actually take place directly towards our prime objects) have similar neurocognitive resources [28, 270, 271].

We can conclude that there is a tight connection between action and perception, and that our selections of actions do not take place in a void but are affected by the possibilities intrinsic in a certain visual environment (our single prime object) [5]. We may postulate that these effects are small because they must not disturb the current actions linked to the subject's goals [5, 21]. Our above conclusions are backed up by Ellis and Tucker (2000) and Tucker and Ellis (1998) [5, 21].

<u>The prime object orientation and the prime object itself is not relevant to the task</u>

Our item attributes (such as the orientation of our prime object) influences the responses even though these attributes are task-irrelevant (but orientation is pertinent to the action afforded by the prime item) [11]. Indeed, our subjects must respond to a target that does not require assessing the orientation of the prime object i.e. the prime object as a whole (not solely its orientation) is not pertinent to the task or ongoing intentions [1, 26, 29]. Indeed, subjects examine the prime object despite the fact that examining any feature of the prime object is not required since the subjects were told to solely examine the target. Such a conclusion is also supported by other studies such as the first experiment by Vainio and Mustonen (2011) (section 28.1 of the review) [37]. That is to say, in our experiments, the leftward or rightward item orientation and the grasp compatibility that is produced by its orientation, was not relevant to choosing the response but still impacted the speed at which the response was chosen and carried out (i.e. the speed with which a specific hand carried out a keypress response) [5]. Hence, compatibility is not between features of an item and the responses executed in regards to the item, but rather between an item and the responses executed to a completely distinct feature of a subject's surroundings (this also applies to Ellis and Tucker (2000) as opposed to Tucker and Ellis (1998)) [21, 5]. In fact, we can suggest that, with respect to our automatic inhibition of motor activations, the motor system is ensuring that unwanted visual data in the surroundings does not substantially impact ongoing behavior [33, 107]. In turn, the probable origins of these unwanted motor activations in a real surrounding do not solely implicate task-relevant components [33, 107]. Thus, our object affordances can automatically produce motor activations although items implicating affordance information are completely task-irrelevant [1, 5, 33]. Other studies support these suggestions [1, 33, 107]. In turn, according to both our experiments and in contrast to other studies described in section 42 of the review, motor activations evoked by the visual attributes of the environment (like item affordances) which do not involve features that are relevant to the ongoing behavior can still give way to self-inhibition mechanisms [33, 107]. In turn, as in previous studies, we can support the idea that the compatibility effect occurs somewhat involuntarily and automatically [1, 26].

The automaticity of the effect

Our findings demonstrate that the processing of the prime objects was implicit and automatic [37, 170]. Ottoboni, Tessari, Cubelli, and Umilta` (2005) (described in section 27 of the review) made this same conclusion for hand identity (i.e. hand primes) [37, 170]. In other words, we can support the account that part of the action-associated information (i.e. in our case, the best suited hand to grasp the item) is illustrated in an automatic way when the item is displayed in the peripersonal environment [5]. This account is also supported by Tucker and Ellis (1998) [5]. Furthermore, in the first experiment of Tucker and Ellis (1998) (which involves a PCE), the response is ascribed to the inversion of the item such that, as opposed to our experiments, their subjects had to focus their attention to the item in an endogenous manner [1, 5]. In our experiments, the activation of affordance information is not limited to cases where the task necessitates endogenous focus of attention to the item i.e. where item recognition must take place [1, 25]. In fact, likewise to our experiments, Handy (2003) shows that partiality regarding attention can take place in the absence of a task that overtly requires subjects to process the items' identity [27, 196]. That is to say, there is automatic attention to our items [27, 196]. In turn, we suggest that the processes of mapping prime object orientation in the motor system can implicate pathways that evade processing stages with respect to identifying stimuli (Vainio and Mustonen (2011) support this suggestion in regards to hand prime identity) [37, 89]. This view proposes that cognitive processes are not necessary to regulate the visuomotor processes involved in the mapping of orientation in the motor system [37]. It is more probable that when the visual and motor illustration association has occurred for prime objects (or hand primes in their experiment), the mapping works automatically within a direct pathway [37]. In turn, the affordance of our item (i.e. its likelihood for action and not the item itself) may be recognised automatically and exogenously (Handy (2003) support this assumption) [1, 196]. Indeed, we may propose that our manipulable items capture attention in an automatic and precise way and this supports the idea that the reach-to-grasp response is visually guided [27, 196].

Attention is not obliged to be focused on the prime item

Although our subjects are told to focus on the center of the screen throughout the entire experiment, there was no central fixation presentation and no mention of the central prime object was given to them in the instructions. Hence, as in the first experiment by Vainio (2007), the orientation of our item can potentiate responses although attention is not obliged to be focused on the item [1]. That is, our manipulable prime objects still give way to action affordances and attract attention despite: 1) being irrelevant to the task and 2) the fact that they could potentially be ignored [1, 196]. Thus, it is not only the item attributes that are pertinent to the action that capture attention [1, 196].

Our prime object is displayed at the focus of attention

It has been proposed that when a restricted focus of attention to the item is enough to execute the task, there is a lack of motor affordance being evoked [1, 6]. However, in the first experiment of Vainio (2007), even if subjects were instructed to recognise the colour of the item and do not have to focus much endogenous attentional resources on the item, item orientation can still potentiate a motor illustration [1, 6]. Thus, they show that the attentional resources can be allocated to the item when the item is shown in a way where its geometrical centre is located at the focus of attention leading to a transient rise in treatment at that position [1, 6, 272, 273]. Hence, in regards to our orientation effects and those in the first experiment of Vainio (2007), the attention is initially focused on a precise spatial location and when the prime item is shown so that its centre is located at the attentional focus, the attentional window is allocated enough on the whole item for the item to give way to response affordances [1]. That is, our subjects are not required by any instructions to focus attention on the item but subjects were told to focus on the centre of the screen and the prime item is displayed centrally which could have led to the orientation effects [1]. Thus, we can argue that the sudden onset of a focally shown item that has features associated with action employs the participant's attention to an extent that is sufficient for creating an action schema linked with the item (Vainio (2007) make the same argument) [1].

Why did we observe a lack of statistically significant PCEs?

We can make a proposition in explaining why we observe a lack of PCE (i.e. facilitation) in our arrow experiment and a non-significant PCE at short SOAs in our dot experiment where as we observe strong NCEs in both experiments. The facilitation priming effect could necessitate a greater amount of attentional resources in order to be visible in contrast to the inhibitory effect [37]. The formation of the facilitation effect could necessitate that enough attentional resources are allocated to the prime object and our short display of the prime object may not be inside the time range for these attention requirements [37]. In contrast, the inhibitory effect generated by the disappearance of the object prime can be demonstrated despite the fact that the treatment of the object prime occurs pre-attentively [8, 37]. Vainio and Mustonen (2011) make this statement for their hand primes [8, 37]. Also, according to the self-inhibition model, we should note that our NCEs could be indicative of prior response activation (even in the absence of a prior PCE) since there could be an immediate inhibition of the activation after the activation is evoked [33, 107].

We support the need for inhibition

In both our experiments, we could postulate that processes that permit representations of motor programmes with respect to seen items must allow inhibition processes that guarantee that the production of motor activation in an automatic manner does not disrupt the ongoing behavior and lead to unwanted actions [26, 23]. In other words, the motor illustrations automatically activated by item affordances have to be inhibited (this account is backed up by other studies) [26]. That is to say, in our experiments, the fact that we observe NCEs supports the idea that, due to motor inhibition mechanisms, the activation of action illustrations produced in an automatic manner by affordances in the environment do not lead to the involuntary execution of the corresponding action (this idea is also supported by other studies) [26, 75]. Hence, in both our experiments, the self-inhibition processes work to avoid the motor effects of the visible visual stimuli that lead to a motor activation which could disrupt the ongoing behavior [33, 135, 141]. Other studies involving the BMP (backward-masked priming) make the same postulation for non-visible stimuli [33, 135, 141]. Our results back up the idea (supported by Vainio (2009)) that if a sensory backing which updates the initial response activation is taken away during the performance of the task, there is an immediate inhibition of the initial motor plan [26, 86]. Likewise to what is explained in section 10 of the review, we support the need for inhibition of illustrations of items with a short display time or items that disappear prior to the response [26, 29, 37]. In section 10 of the review, we go over the importance of inhibition, the impact of distractors and a description of handle affordance effects [26, 29, 79-82]. For our arrow experiment, the inhibition is stronger for short SOAs compared to longer SOAs. We can assume that this inhibition occurs due to the prior automatic activation of a motor illustration [26, 29, 79]. However, this prior activation is not observed in our behavioral results where there is a lack of prior PCEs observed. In other words, in our arrow experiment, there could be an abrupt removal of sensory support for a pre-activated response (although we do not observe a potential PCE trend prior to the NCE in our behavioral results) [8]. Hence, we can not rule out that in our arrow experiment, inhibition processes could be regulated by self-inhibitory mechanisms in motor control [8]. In our dot experiment, according to the potential PCE trend (although it is not statistically significant), we can postulate that the handle affordance of a presented item gives way to an automatic activation of motor illustrations with respect to the hand that fits with the orientation of the handle [29, 79]. Hence, this facilitates matching responses [28, 109]. We can assume that the inhibition (NCE) occurs due to the prior automatic activation of a motor illustration (i.e. the PCE) [26, 29, 79]. Hence, our dot experiment is associated with self inhibitory control circuits which implicate the trend of a biphasic pattern of facilitation before inhibition (other studies support this view) [8, 110, 137]. In our dot experiment, the NCE at long prime-target SOAs could be due to the activation not being strong enough (it does not rise above the activation threshold due to the long prime-target SOA) [33, 29]. To sum up, according to the NCEs in all SOAs of our arrow experiment and the long SOAs of our dot experiment, there is a rapid suppression of an activation possibly since our prime object is removed from view a brief period of time (16ms) following its appearance and prior to the response [29]. In this circumstance, the activation can not rise above the excitation threshold and it is inhibited by the motor system [29]. Once again, this applies to the mug stimuli of Vainio (2011): an NCE was produced by the orientation of an item shown for a brief period of time [29]. In other words, in our experiments, the short prime object display may lead to the NCEs based on the pattern of effects of studies described in sections 34.1 and 34.2 of the review [29, 33, 37]. In both our experiments (similarly to the Vainio and Mustonen (2011) study described in section 28.2 of the review), it is thought that the NCE was due to motor inhibition mechanisms that inhibit the motor activations that are incompletely activated and unsuccessfully updated [29, 37].

Does our effect involve the on-line/dorsal route?

In our dot experiment, since the activation goes down significantly quickly after the item's disappearance, we can back up the notion that this activation is the result of the rapidly updated visuomotor mechanisms linked with the on-line dorsal visual system (this is backed up by Tucker and Ellis (2001)) [11]. In fact, postulations in section 19 of the review regarding the dorsal pathway are relevant to our experiments [11, 155, 158, 7]. Also, in our experiment 2 discussion, we lend support for online visual mechanisms. Yet, the fact that the effect exists with item images may go against the *exclusive* impact of alike neural systems to those involved in the on-line visual regulation of actions since there is a lack of direct interactions (with items) being really afforded i.e. processes linked to on-line visual control mostly involve the actual execution of action on an object [11]. This is supported by other studies [11, 161]. Rather, in our experiments, we suggest that the mechanisms thought to generate motor trends (for possible actions as opposed to actual actions) that involve the afforded grasp-orientation would be more alike to those involved in the preparation of actions [274], and in forecasting likely actions and their sensorimotor impact [11, 77]. This was suggested by studies for the afforded hand shape used to grasp items [11, 77, 274].

Our effects involve micro-affordances

The extent of action illustration would be more alike to specifying the general category of hand grip orientation needed to employ the item, as opposed to the very specific parameter specifications linked with really performing a reach and grasp action [11]. This was also postulated by other studies for hand shape rather than orientation [11]. Hence, in our experiments, we have one component of action, which implicates priming: orientation [21]. Likewise, Ellis and Tucker (2000) have identified two such components of action: the rotation of the wrist and the type of grasp (two distinct types of micro-affordance) [21]. Therefore, a potential view of our effects is that the items primed elements of actions they were linked with [21]. In our experiments, the facilitated actions (i.e. the keypress responses) are due to a specific feature (i.e. orientation) of a grasp action primed by the prime object i.e. it does not implicate grasping as whole being primed, but instead a specific grasp appropriate to the displayed item in terms of orientation [21]. Thus, it implicates the affordance of the particular prime object orientation [21]. Hence, we can use the term "micro-affordance" (defined in section 5 of review) to describe our effects which imply the low-order action attribute of grasp orientation [11, 21]. However, this approach to affordances proposed by Ellis and Tucker (2000) stands in contrast to the Gibsonian affordance (section 5 of the review) which we can not completely preclude [12, 21]. All the above postulations somewhat resemble those of Ellis and Tucker (2000) in regards to hand shape and wrist rotation [21]. In turn, in our experiments, we assess the effect of the prime object orientation (i.e. we do not assess high-order actions but rather what happens at the microscopic level) [5, 57, 58]. Also, in our experiments, without any current intention with respect to the prime objects, the type of motor illustrations automatically evoked by a visual item could be anticipated to stay restricted to visuomotor primitives (i.e. simple such as our orientation or such as hand shape or wrist rotation in other experiments) that are similar for multiple different actions [11]. This stands in line with the concept of micro-affordances and this notion is backed up by Tucker and Ellis (2001) [11]. To sum up, our compatibility effects are associated to the micro-affordances that each item evokes regardless of the subject's goal, and thus, alike effects must be observed for other attributes of actions (other than our orientation attribute) [21]. Postulations in section 5 of the review regarding the explanation of micro-affordance apply closely to both our experiments [5, 11, 21, 26].

Our effects may involve the direct path to action

Our experiments could involve the direct vision-to-action path (section 7 of the review) which does not require semantic knowledge [11]. Other studies involving higher level item-action connections back up this direct path [11, 67-69]. In other words, our experiments could fit with the account suggested by Humphreys and Riddoch (2001) that there is a direct pathway in the brain going from vision to action that relies on action templates activated by item affordances [198, 199].

The role of the goals to act

Here, based on Tucker and Ellis (1998), we propose two opposing views regarding the role of the goals to act [5]. The first is supported by both our experiments where the subjects have no overt goals to act on the prime object [5]. However, we can postulate that there is an illustration of distinct visual data by the subjects when they are presented with the prime object [5]. We mostly focus on reach-to-grasp actions using the hand muscle orders which are generated by the transformation of visual data from the prime object [5]. Likewise to Tucker and Ellis (1998), we support the option that visual items prime actions despite the lack of overt goals to act [5]. That is, we support the view that the actions that an item affords must be made available in a way that does not depend on our intentions since our prime object's orientation and our prime object itself were irrelevant to the task or ongoing intentions (this account is supported by other studies and discussed in section 9 of the review) [11]. In contrast, the opposing view suggests that the employment of vision to regulate actions has normally been understood as an issue that starts with the goal to act and the manner in which we would use visual information relies on the purpose of the action [5]. In this vein, the action goal determines: 1) the illustration of distinct visual data and 2) the transformation of that data into quite distinct muscle orders [5]. In fact, as addressed in section 9, some studies propose that our immediate intentions are important in settling the pertinent visual information, as well as which affordances have to be retrieved to carry out those intentions [11].

Our effects are not due to a single fixed feature of the items: we utilized several different objects

In our experiments, we show the retrieval of action-associated components from a range of distinct visual components [5, 21]. In fact, our experiments with respect to SRC back up the notion that some action-associated attributes of items evoke automatic response codes [5]. It is not accurate to assume that one single attribute of every item corresponds to a specific action [21]. These conclusions in regards to our experiments are supported by Ellis and Tucker (2000) and other studies [5, 21]. In other words, in our experiments, we could propose that the orientation effects involve the notion that an item's orientation can be recognised from different item attributes

(Vainio, Ellis and Tucker (2007) examines this proposition) [1]. Furthermore, as stated in their study, in our experiments, items from every different category (refer to experiment 1) have attributes with respect to which the response code associated with orientation can be retrieved in a different way [1]. In addition, Ellis and Tucker (2000) mention that their effects are quite consistent due to the fact that they can be shown with several different types of actions across several different experimental designs [21]. This consistency of the effect is supported in our experiments since the effect is shown with different types of actions due to the fact that we employed several different kinds of prime object stimuli [21]. Indeed, in both our experiments, an advantage is that we employed 32 different images of common graspable manipulable prime objects (with affordances) (instead of for example distinct kinds of mugs in Vainio et al. (2011) [29] and Vainio (2014) [26] or a hand prime in Vainio and Mustonen (2011) [37] or four frying pan images in Phillips and Ward [25]). Yet, we still found NCEs which mirrors the negative priming effects observed in other studies (such as Vainio et al. (2011) [29] and Vainio (2014) [26]) and supports the fact that our effects are substantially robust and can be easily generated with different types of objects [26, 29]. In fact, Vainio (2014) suggest that it is not probable that inhibition processes are present solely for regulating the affordance effects linked to mug handles despite the fact that, in their study, their demonstrated negative priming mechanisms are only associated with mug handles [26]. Hence, there is a high probability that identical regulation processes take place during response hand selection in terms of any item's handle affordance [26]. Indeed, in our experiments, regardless of the inhibition mechanism involved, we support a similar argument that this mechanism would not be limited to specific objects since our effects were observed with 32 distinct prime objects. Therefore, we could not suppose that all items have an identical attribute that corresponds to an identical action and leads to the effect [21, 5]. For example, we have different categories of objects being grasped some with a handle and some without a handle or some with a principle axis of elongation and others with an orthogonal handle (see our first experiment) [5, 21]. Therefore, in our experiments (as in Tucker and Ellis 1998), a key finding is that compatibility effects, of a stimulus attribute (prime object orientation) non-relevant to the choice of a response (to the target), are demonstrated with a significant diversity of natural items [5]. In section 36 of the review, there is a description of what the diversity of the employed items entails (which mostly applies to our experiments) [5]. Moreover, the postulations in section 43 of the review regarding the fact that there is no fixed perceptual attribute that leads to the retrieval of a relevant code apply to our experiments [21]. In other words, our item orientation is not a fixed visual attribute of the task presentation (this notion is explored in section 36 of the review and most of the connected assumptions apply to our experiments) [5]. In turn, which feature of an item cues a specific hand (right or left) changes throughout the set of stimuli used in our experiments [21]. Thus, as in Tucker and Ellis (1998), our item orientation was extracted across the stimulus set, although the input with regards to perception establishing orientation was greatly modified for every individual item and was task-irrelevant [5]. Also, in line with what is explained above, we could postulate that there could be distinct time courses for retrieving orientation information depending on our prime object being displayed [37, 170]. We base this assumption on the fact that Ottoboni et al. (2005) (section 27 of the review) demonstrated a negative and positive SRC effect with the palm-view and back-view hand image, respectively and that a possible explanation they give for this is that there are distinct time courses for retrieving identity information depending on the hand view [37, 170].

Another impact of employing several distinct prime objects

The use of a single item stimuli in Phillips and Ward (2002) as opposed to several distinct prime objects in Vainio, Ellis and Tucker (2007) (section 29 of the review) may have led to differences in temporal features of their orientation effect [1, 25]. In our experiment, if we had used solely a single item (like the one frying pan of Phillips and Ward (2002)), the object representation of that one item would be: 1) active across the experiment, 2) enhanced by knowledge associated with the action and 3) it would result in a rise in the facilitation of generating the response code linked with the position of the functional handle [1, 25]. This type of semantic repetition could make the treatment of action-pertinent item features easier [1, 260]. In contrast, in both our experiments, as in Vainio's study (which used 30 distinct prime items), the object representation was not pre-built for a subsequent prime item since we employed 32 distinct prime items (there was no prime repetition) within a given block (although we did repeat the same set of 32 images for each of the 8 blocks where each block had a different SOA) [1, 25]. Hence, solely the orientation attribute (without the impact of the functional handle position) was retrieved for the production of a response code [1]. This distinction in access to action-associated knowledge of the object due to prime repetition could give way to distinct temporal features [1, 275]. Also, we removed this type of semantic repetition which may facilitate the treatment of item attributes that are pertinent to action [1, 260]. In turn, our experiments may differ in this sense from other experiments and have the advantage of retrieving solely the visual orientation attribute to produce the response code [1].

<u>The advantages of using images of common actual items</u>

As in Tucker and Ellis (1998), we used stimuli pictures of real items since differences in their spatial attributes affect the actions that can be assigned to such items [5]. Our prime objects had high visual complexity [198]. Indeed, they were common actual items that were in 3D, rotated in depth and graspable (likewise to items in the real world) and they give way in an instinctive manner to the affordance of a great range of actions i.e. our stimuli have actual real implication for action [5, 12, 198, 221, 222]. Based on all experiments by Symes, Ellis and Tucker put together in terms of PPAs (summarized in the review), these features of our items could have made the affordance effects we found more robust [198]. Also, these features stand in contrast to previous SRC studies which utilize stimuli with no real implication for action i.e. their stimuli vary on a restricted amount of abstract attributes (such as color or position) and, in turn, compatibility effects seem to occur in a somewhat abstract manner [5]. Also, as opposed to the stimuli of other studies like Symes, Ellis and Tucker, all our objects are shown as if a subject could pick it up or manipulate it which could have added to the strength of our effects [198]. Our 3D object images are more likely to generate an OSC effect as opposed to images of items in 2D [12, 198, 221, 222]. The orientations of our 3D objects provide a sufficient amount of action-pertinent information to produce an affordance effect (in section 51 of the review is a description of the impact of item dimensionality) [198]. Moreover, as in other studies, our experiments could fit with the idea that our everyday actions are established by meaningful and non-abstract connections between the visual surrounding and the action systems of the participant [5, 174, 175]. Also, as in other studies, we could assume that the production of response codes that rely on data with respect to possible actions only occurred since we utilized stimuli which intrinsically have implications for actions [5, 174, 175].

<u>Our supraliminal conscious prime objects still give way to NCEs (inhibition)</u>

In our experiments, there are inhibition processes with prime stimuli in the absence of a mask, when the activation of the motor responses is supraliminal and there is conscious perception of the stimuli (i.e. the prime objects) [8]. However, many statements in section 11 of the review could still apply to our experiments including those regarding subliminal unconscious stimuli and the importance of inhibition [8]. In both our experiments, we use conscious stimuli but for both conscious stimuli and subliminal stimuli, there is inhibitory regulation and mechanisms [8, 102-105, 53]. Indeed, our primes are not masked and are visible (i.e. there is conscious awareness of the stimuli) and they still lead to NCEs. This contradicts a conclusion made in other studies that suprathreshold primes only give way to PCEs [8, 124, 135]. That is, according to the masked-priming paradigm, when the stimuli are supraliminal, researchers find PCEs where as we found NCEs even though we only employed supraliminal primes which, according to their hypothetical threshold hypothesis, would surpass the activation threshold [8, 29]. We could also postulate that supraliminal primes can give way to response activation (i.e. lead to their matching response) prior to inhibition which occurs if the strength of the initial activation surpasses the inhibition threshold (Eimer makes similar postulations for unconscious stimuli and subliminal primes) [8]. Also, since our prime objects are supraliminal, we may in theory tend towards endogenous inhibition. Yet, our prime object is task-irrelevant and has a very brief duration (16 ms). Furthermore, no instructions were given regarding the prime objects and subjects are not instructed to allocate endogenous attention to them. Hence, the postulations for the masked priming task (involving elements of exogenous inhibition) may apply to our experiments [8]. Also, we do not preclude the idea that exogenous and endogenous inhibition may rely on notions which are not entirely different and we could argue that they do not in all circumstances work in an independent and entirely different way [8, 110]. Eimer and Schlaghecken (2003) support these assumptions [8, 110].

<u>A contrast between our experiments (as well as those of other authors) with the BMP</u>

Here, we go over some distinctions between the studies by Eimer and Schlaghecken (1998) (regarding the masked- priming paradigm i.e. BMP), Vainio (2011), Vainio and Mustonen (2011) and both our experiments in terms of NCEs [29, 37, 107]. The purpose is to show that the contrast between our experiments and the BMP could be due to the distinct prime/target stimuli or/and the distinct basic inhibitory processes [29, 37, 107]. We will first address the latter. In the BMP (described in sections 15 and 16 of the review), the NCE occurs when two conditions are met: 1) there is backward masking and a subliminal display of the prime arrow and 2) the prime includes components that are pertinent to the current task [8, 29, 107]. For instance, in regards to this second condition, the NCE was absent when arrows were employed as primes but letters were employed as targets [29]. In our experiments (and in Vainio (2011) [29]), the NPE (i.e. NCE) indicative of inhibition was observed due to the handle (or graspable part) affordance in other conditions (than those of the BMP): 1) the prime does not include attributes that are relevant to the task (i.e. the prime object itself and its orientation are task-irrelevant), 2) it does not occur prior to a backward mask, 3) it is not presented in a subliminal manner (our display was supraliminal) and 4) the prime feature (which evokes the initial response activation) is not the same as the action feature in regards to which responses are executed (as opposed to, for example, both the prime and target being arrows oriented to the right) [8, 26, 29, 33, 107]. These conditions also apply to Vainio et al. (2011) [29, 33]. Also, both our experiments are similar to the NMHP (the finding based on Vainio et al. (2014) and Vainio et al. (2011) and described in section 25 of the review [26, 29]) in the sense that they involve the same distinctions (between the BMP and NMHP): 1) the NMHP took place even though the prime is supraliminal and 2) the NMHP took place even though the prime did not include attributes that could be at all task-relevant [26]. In fact, in our experiments as well as in Vainio and Mustonen (2011): 1) the NCE can be seen even when the prime object and prime hand (respectively) are evidently observable and 2) the NCE was present regardless of the fact that the prime object and prime hand (respectively) did not include components that are pertinent to the current task [29, 37, 107]. In turn, the NCE was present with the prime object and prime hand regardless of the present goals or tasks [29]. However, Vainio et al. (2011) [29] proposed that the NMPH and the results of the BMP (i.e. the experiments by Eimer and Schlaghecken described in sections 15 and 16 of the review [8]) could be generated by alike motor self-inhibition mechanisms which may also apply to our NCEs [26, 29, 33, 86]. In fact, in both our experiments, in cases where response activation is produced by a realistic prime item such as the handle affordance of an item [29, 33], and the prime does not contain attributes that are pertinent to the current task, the participant does not have to be unconscious of the prime in order to observe the negative priming (this is supported by Vainio (2011) for hand primes in section 42 of the review) [29, 33, 133].

The impact of the prime being distinct from the target

Now, we will address how the impact of distinct prime/target stimuli could account for differences between our experiments and the BMP. Vainio (2011) propose the idea that, in the BMP, surpassing the hypothetical activation threshold (described in more detail later) is facilitated during the active recognition of the target arrow by the fact that the prime is an arrow as well and that it is presented at the same place as the target [29, 107]. In such a case, top-down processes associated with the task may be aiding the positioning of attention to the prime and emphasizing its treatment

[29]. In turn, if the prime is presented in a supraliminal fashion, the activation generated by the prime surpasses the activation threshold (leading to a PCE) [29]. Hence, in the BMP, an NCE can only be evoked with primes displayed in a subliminal fashion [29]. In contrast, based on Vainio (2011), in both our experiments, when the motor activation is generated by an item affordance like the handle and the prime does not include any components that could be pertinent to the task, the top-down mechanisms linked to the task do not emphasize the treatment of the prime [29]. In turn, it would require a long onset duration of the prime to lead the activation generated by the prime to surpass the threshold (giving way to a PCE) [29]. In fact, in Vainio (2011), the threshold was surpassed (i.e. there was a PCE) when the prime was presented for 370 ms (a long duration) and in our arrow experiment we go towards the PCE at longer SOAs (which makes sense if we consider this long SOA to be equivalent to a long prime duration as will be explained later) [29].

As a side note, an advantage to both our experiments is that our targets are not reiterations of the prime objects (i.e. they are not identical stimuli) which rules out the option of "repetition blindness" (described in section 46 of the review) i.e. the NCEs are not caused by a perceptual bias that goes against the repeated treatment of an identical stimulus [8, 120, 121, 211, 212].

Two distinct inhibition processes

Likewise to research by Vainio and colleagues, we can not rule out that the NCE we demonstrate could be: 1) a specific instance of the self-inhibition effect described by Eimer and Schlaghecken (1998) (i.e. the BMP) or 2) a completely new and distinct motor inhibition effect [29, 37, 107]. Indeed, it is still unknown whether the NCE found in Vainio (2011) as well as Vainio and Mustonen (2011) is attributable to one or the other of these two options [29, 37, 107]. In turn, our inhibition process may resemble that of Vainio and colleagues [29, 37, 107].

A contrast of the temporal features of our experiments to those of the masked-priming paradigm

Here, we will compare the temporal features for our experiments to those in the BMP (mostly studies by Eimer and colleagues) [8]. In our experiments, we attempted to observe behavioral results that back up the initial response activation by altering the time lapse or stimulus onset asynchrony (SOA) between prime and target [8, 121]. That is to say, as in studies by Eimer, we attempted to evaluate response selection to the target in the midst of the activation phase which takes place early on [8, 121]. Our arrow experiment has some similarities to those of Eimer and colleagues (section 13 of the review) [8, 134, 107] such as the fact that they both involve target arrows. Other features of their BMP are similar to both our experiments (for instance, we also display the prime object for a brief period of time of 16 ms) [8, 107]. Some distinctions between the BMP and both our experiments include the fact that we did not use a backward mask, the prime object remains visible (i.e. supraliminal and not subliminal) and the prime is not an arrow but rather a central object such that we can assess affordances [8, 107]. In their experiment, they find a PCE at short ISIs and an NCE at large ISIs where as in our arrow experiment, we see a decreasing NCE which is largest at short prime-target SOAs and decreases as the SOAs rise [8, 107, 121, 120]. Also, we can postulate that we may have observed a PCE if we used an SOA above 600 ms. In our arrow experiment (where we did not assess LRPs), there may be a response activation prior to the inhibition but this is not observed in our behavioral results i.e. there is no statistically significant PCE or potential trend towards it [8, 107, 121]. Thus, their findings described in section 13 of the review and our arrow experiment are not consistent and are contradictory.

In contrast, in the dot experiment, the results are similar to the BMP (section 12 of the review) [8]. In our dot experiment, in terms of RTs, the results tend to a potential PCE trend at short SOAs (even though it is not statistically significant) i.e. the selection of a response occurs at a moment in the initial activation stage and performance is not yet influenced by the inhibition of the response linked to the prime [8, 121]. However, at long SOAs, there is an NCE since the selection of a response takes place at a moment in the later inhibition stage [8, 121]. This backs up self-inhibitory mechanisms of the motor system i.e. a reversal of the initial effects which is thought to be a subsequent inhibition of the initial activation [8, 29]. This inhibition takes place because the long SOA removes the sensory backing that updates the early response activation [8, 29]. The "near-threshold" stimuli produce an incomplete motor activation which is processed by the motor system as an unwanted activation due to the fact that it could eventually give way to an unwanted overt behavior [8, 29]. Therefore, the inhibition of this response activation takes place instantly [8, 29]. In other words, in our experiments, we could propose that response inclinations are inhibited by self-inhibition mechanisms if facilitatory inputs like visual sources are not giving way to a sufficient degree of activation [8, 33]. All of the above postulations regarding inhibition are supported by Eimer & Schlaghecken (2003) in regards to the BMP [8, 29, 33]. Moreover, our negative priming in the dot experiment is similar to the negative priming effects shown with the BMP: the negative priming rises and goes down rapidly after the removal of the prime (i.e. it moves from a PCE to an NCE which in turn goes back down) [33, 107, 138, 276]. Hence, our dot experiment fits with the account of the LRP assessment described in sections 15 and 16 of the review [8, 33, 107]. Indeed, they have similar temporal attributes: there is a biphasic trend of activation followed by inhibition [8, 107, 120, 121]. To sum up, we do not rule out that our NCEs in both our experiments may be potentially caused by self-inhibition mechanisms of the motor system (similar to those of the BMP and previous research) [8, 29, 37, 86, 107].

<u>The temporal features of our effects and associated conclusions</u>

Once again, our results offer support that allocating attention to a visual item leads to the activation of motor components linked with the actions afforded by the item [11]. This conclusion is also supported by Tucker and Ellis (2001) who found: 1) the compatibility effects to increase in size during the time the item stays visible but 2) to fade away quickly after the offset of the item [11]. In our experiments we could not assess their former finding since our prime object stays visible for a constant short amount of time of 16 ms i.e. this is not altered. What is altered is the 8 SOAs (from 0ms to 600ms) between prime and target which allows us to assess their latter finding. In our experiments, the prime objects themselves are not pertinent to the task and do not stay visible (i.e. they are removed prior to the target) and we find in our dot experiment (likewise to Tucker and Ellis (2001) [11]) that the compatibility effects do fade away after the disappearance of the prime object i.e. it moves from a potential PCE trend (that is statistically insignificant) at short SOAs to an NCE as the SOA increases. Hence, there is a decrease and eventual reversal in the compatibility effects as the SOAs increase. That is, the priming of compatible orientations decreases quickly after item offset i.e. the effect is rapidly affected by any variations in the visual input [11]. Hence, this attribute fits with the account (we stated previously) that the compatibility effects can be produced from automatic visuomotor transformations occurring inside the dorsal processing stream and its projections to the motor areas [11]. In other words, the effects of our dot experiment might have as their source the dorsal treatment of item features that are pertinent to action [11]. This account is also supported by Tucker and Ellis (2001) in regards to grip type (such as in their fourth experiment) [11]. In fact, our dot experiment in particular fits with the view that the priming effect of the visual item on the motor system is somewhat transient/temporary, it quickly decreases if the prime object is removed prior to the response being signalled and in turn it is probably a consequence of the quickly refreshed representational processes in the dorsal system [11]. This view is also highlighted by Tucker and Ellis (2001) such as in the second portion of their fourth experiment [11]. However, the tasks of our experiments (as well as theirs) reduce the probability that the visuomotor transformations implicated are entirely identical to those implicated in the on-line regulation of actions (for reasons described previously in this discussion) [11]. Rather, similarly to Tucker and Ellis (2001), we can propose that other systems within parietal and motor areas and potentially non-dorsal areas, could play a role in the production of illustrations of possible actions which fit with the visual input [11].

On the other hand, in the arrow experiment, the effect moves in the reverse direction i.e. the NCE decreases with increasing SOAs (there is a move towards a PCE) and we could expect a PCE (although this was not observed) at longer SOAs than 600 ms. In other words, the increased prime-target time interval gave way to a rise in the priming effect (in the positive direction) of the visual items on the motor system. That is, in the arrow experiment, the priming of compatible grip orientations increases as the time interval after which the prime object is removed increases. To sum up, likewise to what is postulated in the Mattler study (described in the review and addressed later in the discussion), in both our experiments, the effects could be restricted to the precise time courses we utilized and could possibly not be found with distinct time courses [111].

<u>The logic supporting the findings of our arrow and dot experiments</u>

Here, we will postulate two entirely distinct logical explanations for our results in the arrow and dot experiments. In order to do so, we will first go over the manner in which another example of a handle affordance study relates to our experiments [26, 29, 33]. In their first experiment, Vainio (2011) examined the notion that there would be a quick inhibition of the motor illustration which is generated by the item's orientation if the item is presented for a short period of time [29, 37]. They find that, when the prime item (a mug with a handle pointing to the left or to the right) is shown for a short period of time (30 or 70 ms) before the display of the target arrow (to which subjects had to make a right keypress response for an arrow pointing to the right and a left keypress response for an arrow pointing to the left) [29], there is an NCE between item orientation and responding hand [29]. In contrast, when prime onset durations are greater (170 or 370 ms), there is a PCE since the prime generates a motor activation that rises over the hypothetical threshold for finding PCEs [29]. Hence, in contrast to brief prime onset durations, greater prime onset durations lead to the lack of inhibition after motor activation [29]. However, they vary the actual duration of the prime where as in both our experiments, we keep the duration of the prime object constant and short (at 16ms) and vary the prime-target SOA [29]. In terms of the arrow experiment, the logic for our findings is based on accepting an equivalency between modifying the prime duration and modifying the prime-target SOA. If we do so, we find similar results to those of Vainio (2011) i.e. an NCE for short prime durations and short SOA and a PCE for long prime durations and long SOAs [29]. The NCE (which decreases with rising SOA in our arrow experiment) implies negative priming indicative of quick and strong motor inhibition. Also, in our arrow experiment, we don't actually observe a PCE but we can postulate that due the fact that the NCE decreases with SOA, we may observe a PCE beyond the 600 ms SOA which would be indicative of motor activation. This PCE would be similar to the positive handle affordance effect found in Vainio (2011) [29] when the prime mug is displayed for 370ms (a long duration) [26, 29]. In fact, in the methodology employed by Ottoboni et al. (2005) as well [37, 170] (section 27 of the review) in order for the strong facilitation (generated by the observed hand's identity) to occur, it may require more than 100 ms for the display time of the prime hand [37, 170]. Thus, in our arrow experiment, the fact that the NCE decreases with rising SOAs (i.e. increased facilitation with rising SOAs) matches the fact that facilitation may require more than 100 ms in Ottoboni et al. (2005) (although 100 ms represents their prime duration where as we assess prime-target SOAs) [37, 170].

Therefore, the logic for the findings of the arrow experiment is as follows. If we consider a short prime display to be equivalent to a short prime-target SOA and a long prime display to be equivalent to a long prime-target SOA, then we can understand that short SOAs are indicative of briefly displayed primes which may require more inhibition than longer displayed primes since we don't want to allow objects displayed briefly in our environment to affect behavior and these affordance activations should be in turn inhibited. In contrast, an object that is observed for a longer period of time would require less inhibition since it may be more relevant to the ongoing behavior. In our arrow experiment, we postulate that the short duration of the prime and the short prime-target SOA (which we consider in our arrow experiment to be equivalent to a short prime duration) block the sensory support of the prime (i.e. do not permit the motor system to access the sensory support necessary to keep up the primed response), leads to the removal of the prime's neural illustration and this evokes self-inhibition [134, 107, 144].

On the other hand, in our dot experiment at short SOAs (i.e. response activation), there is a PCE (although not statistically significant). At long SOAs, there is an NCE. The potential logic is that at short SOAs, there is a strong sensory support from the prime object given that it has not been a long time since the prime object appeared [134]. Hence, the results tend to a PCE [134]. In other words, if sensory traces evoked by the prime are not entirely removed (due to the short SOA), the initial primed response activation will go on giving way to PCEs (as opposed to NCEs) [134, 217]. However, as SOAs increase, it has been a longer amount of time since the prime object appeared which decreases the sensory support or backing for the prime object (preventing the updating of the initial response activation) and leads to a decrease in the PCE and eventually a reversal to the NCE which is indicative of affordance inhibition [8, 134]. In other words, in our dot experiment, the long prime-target SOA itself (not a mask) can block the sensory support of the prime because of the greater interval between prime and target which removes all illustrations linked with the prime and this evokes the self-inhibition which works as an emergency brake mechanism to supress a response tendency that is outdated [134, 107, 144]. Hence, the inhibition increases (i.e. a larger NCE is found) as the prime-target SOA increases. That is, in the dot experiment, there is an abrupt removal of sensory support for a pre-activated response (PCE) (ending the initial activation phase) probably due to the long prime-target SOA which leads to an NCE [8]. Also, we observed a potential PCE trend (although not statistically significant) at short SOAs despite the fact that the duration of the prime object is short (16 ms) in all conditions.

<u>Contrasting the temporal features of our effects to those of the Simon effect and Phillips and Ward</u>

Once again, in our dot experiment there is a potential PCE trend at short SOAs (although it is not statistically significant) and we could expect a PCE in our arrow experiment at longer SOAs than 600 ms (although we did not actually observe that). Hence, in the potential PCE trends of our experiments, we demonstrate an advantage for matching over non-matching mappings between handle orientation and hand of response [25]. In Phillips and Ward (2002) (described in the review), the advantages of matching between the prime's handle and the hand of response increased progressively throughout a time interval of 1200 ms (the SOA between the display of prime and target) [25]. In fact, their trend of findings was alike in all three of their experiments demonstrating that the correspondence effect increases progressively with time (for around 1 second) and lasts for a large amount of time [25]. In other words, this is similar to an increase in the PCE as the SOA increases. Indeed, in Phillips and Ward (2002), during the display of images of actual functional items, when the time during which the subjects saw the item rose, the magnitude of OSC effects rose in a linear manner [25, 198]. However, there is an important difference between their experiment and our experiments: in the former, the prime and target both stayed visible up to the response where as our primes disappeared followed by the blank screen SOA before the appearance of the target [25]. In other words, our SOAs involved the interval between prime offset and target onset where as their SOA involved the actual prime item display prior to the onset of the target [1, 25]. Also, we used distinct SOA intervals which may also account for any differing findings (especially in the results of our dot experiment) [25].

Also, in Phillips and Ward (2002), the trend of response activation from the non-pertinent prime affordance is very distinct from the non-pertinent response activation observed in the Simon tasks [25]. In Simon tasks, response activation due to a non-pertinent stimulus feature fades away following a significantly briefer time period of around 200 ms [25, 172, 277]. The authors do not propose necessarily that every automatic behaviour has to demonstrate such an identical quick time course and certain automatic behaviours may be produced solely in a gradual manner [25]. Yet, the notion of any adaptive benefit in terms of evolution from the perception of affordances on automatic response might implicate the effect being quick and instant [25]. Thus, the notion of an increase throughout time intervals of around 1 s may not be completely consistent with the overall notion of automaticity in terms of function, or "direct path" to action [25, 72].

In terms of temporal features, our dot experiment fits more closely with the Simon tasks where as our arrow experiment fits more closely with Phillips and Ward (2002) [25]. Thus, our findings for the dot experiment (which oppose those of Phillips and Ward) seems to fit with this latter overall notion of automaticity. Indeed, in our dot experiment, the fading away of the effect (from a potential PCE to an NCE with rising SOA) is similar to that of the Simon tasks (the potential PCE trend is greatest at short SOAs making the effect quicker and instant) [37, 172]. In our arrow experiment, the advantages of matching between the prime's handle and the response hand increased progressively throughout SOAs (as in Phillips and Ward) [25]. That is, in the arrow experiment, the correspondence effect increases (i.e. there is a move in the direction of NCE to PCE). In turn, we cannot make the same conclusions as the dot experiment or Simon tasks. Also, in their first and third experiments, the Vainio and Mustonen (2011) results for hand prime identity (described in section 28.2 of the review) are alike to the temporal features of response activation produced by item orientation in Phillips & Ward (2002) and our arrow experiment [25, 37, 172].

The impact of the short presentation of the prime object

In both our experiments, the fact that our prime objects were presented for a brief period of time did not hinder the influence of the prime object on target discrimination [28]. Also, many studies have shown that SRC effects can be particularly influenced by changes in the onset durations of the prime [37, 8, 170]. For example, in Vainio's experiments described earlier, the actual duration of the prime (which we kept constant and short in both our experiments) can influence the SRC effect [26, 29]. Yet, in our experiments, it is the prime-target SOA (not the prime duration) that impacts our SRC effects [26, 29]. In addition, the fact that we found NCEs in both our experiments (although with a different time course) supports the view that a brief display of prime items can be strongly linked with motor inhibition (other studies also support this) [8, 29, 37, 107]. For example, studies have shown that commonly found positive SRC effects can become NCEs: 1) when the prime is presented too briefly to employ enough processing resources and 2) if the prime disappears from the presentation prior to response choice [8, 37]. Thus, in both our experiments, we may see NCEs for these two reasons. Indeed, based on conclusions by Ottoboni et al. (2005) (section 27 of the review), in both our experiments, the fact that the prime object always disappears prior to the hand response choice could have biased or influenced our SRC effect [37, 170].

However, in both our experiments, the processes implicating the mapping of the prime object's orientation to the motor system could be sufficiently quick so that the orientation can be retrieved from the prime object and mapped to the motor system although the prime object is shown briefly [37, 107, 170]. In turn, the process implicating the mapping of the object affordance (involving object orientation) to the motor system could occur more rapidly than the cognitive mechanisms for the selection of response hand with respect to the target [37, 107, 170].

Temporal features of our effects: the NCE (i.e. inhibition) fades away

We can compare the time course of the Vainio and Mustonen procedure explained in section 28.2 of the review (for their fourth experiment) to the time course employed in our experiments [37]. In their fourth experiment, their SOA 1 condition (where there is an overlap in the display of prime and target) showed a negative SRC effect [37]. However, there appeared to be a decrease in this negative SRC effect for the SOA 2 condition where the target onset was postponed for 150 ms [37]. In both our experiments, short SOAs are similar to their SOA 1 condition and long SOAs are similar to their SOA 2 condition [37]. In our arrow experiment (with similar findings in terms of temporal features), we can potentially make a similar conclusion: the motor inhibition linked with the prime object's removal stays solely for a short period of time [37]. In our dot experiment, as opposed to their findings, the NCE increases as prime-target SOA increases. However, at even longer SOAs (300 ms and 600 ms), the NCE decreases again. Hence, we can postulate that the motor inhibition linked with the prime object's removal stays solely for a certain period of time as well and the inhibition effect eventually fades away [37, 119]. Also, many of the postulations regarding illustrations in the motor system described in section 28.2 of the review with respect to Vainio and Mustonen (2011) can be applied to our experiments if instead of considering an observed prime hand, we consider a prime object involving affordances [37].

Introducing the abstract response coding view and research opposing this view

Our experiments do not rule out other interpretations than the action potentiation account [5]. The results of Tucker and Ellis (1998) and other studies (section 30 of the review) also propose other interpretations [5]. In our experiments, it could be an option that item orientation was assigned in an automatic way an abstract response code with respect to space and that this was the cause for the demonstrated effects [5]. This is called the abstract response coding view (section 34 of the review) [1]. In this case, the results of our experiments could be seen as a Simon effect of a non-pertinent spatial stimulus parameter (i.e. item orientation) [5, 60]. Thus, in our experiment, there are two options that could account for the influence item orientation has on response time: 1) abstract spatial coding of orientation based on a left-right attribute (i.e. where the abstract left right coding of the item's horizontal orientation gives way to the activation of a response in an automatic manner) and 2) the automatic activation of a response code grounded on the best suited hand for grasping the item (i.e. the action potentiation account which includes the grasp compatibility of the item) [5]. These two options are also proposed by Tucker and Ellis (1998) [5]. In other words, in both our experiments, both possible conclusions (described in sections 31, 41 and 42 of review) may potentially apply: 1) abstract spatial attributes of the prime object produce the effects due to the fact that the item's handle or graspable part gives way to an image that is horizontally asymmetrical or 2) the handle affordance of the displayed prime object produces the compatibility effect (action specificity) [29, 25]. The former postulation itself could involve two options: 1) the handle or graspable part of the prime object could have a shape with attributes alike to those of arrows and 2) there could be a spatial compatibility effect (i.e. a Simon effect) due to the handle or graspable part comprising the greatest saliency with respect to the horizontal display of the item [29, 38]. These options (described in section 31 of the review) are proposed in Vainio (2011) [29, 38, 60, 107]. Tucker and Ellis (1998) mention that a method with which they could examine the relative influence of both options would be to look at a modification of their first experiment by using a single hand to respond [5, 179]. In other words, as described in section 30 of the review [5], they assess in their second experiment, the relative implications of abstract coding and action specificity when they instructed a response to the orientation of the target (upright or inverted) by employing two fingers of the identical hand, instead of fingers of different hands (like their first experiment) [25, 5]. For example, Simon effects can be demonstrated when the subject employs two fingers of one hand to execute the responses [37, 278, 25, 179]. Based on their findings with a single hand (i.e. no compatibility effect between item orientation and response side [5, 25, 179]), we can make a similar conclusion in our experiments: the compatibility effect involves action specificity (not abstract coding) [5, 25]. In our experiments, we did not examine this since we did not employ experiments with a single hand but their findings could apply to our experiments [5, 25]. Indeed, as demonstrated by other studies, we could postulate that our OSC effects are distinct from other spatial compatibility effects like Simon effects [5, 6, 38, 198]. Likewise, if we base our experiments on the second experiment by Vainio and Mustonen (2011) (section 33 of the review), we would also conclude that the interaction between prime object orientation and left-right response would not be significant when the subjects perform the responses with two fingers of the same hand and, hence, the SRC effect of our experiments would not be caused by abstract coding [33, 37]. Thus, based on their study, we can also conclude that our effects are not due to abstract processes in regards to cognition or perception [33, 37]. The second experiment of Vainio et. al (2011) (section 25 of review) also supports the affordance view as opposed to abstract coding [29].

Furthermore, in our experiments, the fact that the left or right irrelevant orientation of a set of different natural items evokes compatibility effects backs up the notion that it is the pertinence of this attribute for action that causes the left-right coding [5]. Thus, coding is most likely produced from the potentiation of precise actions (afforded by the prime objects) which comprise a reach by a precise hand [5]. These assumptions also apply to Tucker and Ellis (1998) [5]. Therefore, based on Tucker and Ellis (1998), in our experiments, the orientation of an item, when shown across a series of natural items, is not likely to generate a simple stimulus code (to the left or right) which may overlap with a response attribute (to the left or right) [5]. Still, it does facilitate or deter responses made by the left and right hands, which means that the key characteristic may be the connection between item orientation and the hands rather than simply the set up of the response keys to the left or right [5]. Tucker and Ellis (1998) back up these postulations [5].

Yet, we also presume that the two kinds of coding (items causing action priming and the abstract coding of item orientation in terms of left and right) do not rule out one another but the former option is best upheld by Tucker and Ellis (1998) [5]. Thus, in our experiments, our accounts of SRC implicating the actions potentiated by visual items do not substitute or preclude other more abstract coding accounts (this notion is addressed in section 37 of the review) [5, 186, 187]. Indeed, we can't rule out that there may be partial abstract response coding in our experiments but based on studies like Vainio and Mustonen (2011), this account for the effect as a whole is not probable [37]. That is, in our experiments, as in Tucker and Ellis (1998), we could propose that action-associated codes can add to, rather than substitute, other coding views of SRC effects to cases where the changing attributes have a natural bearing on actions and are not fixed perceptual features of the presentation (section 30 of the review has a description of both options and what they entail) [5]. Also, many arguments question these findings by Tucker and Ellis [5, 25].

<u>Some support for the abstract response coding view</u>

To back up the abstract coding account, Phillips and Ward (2002) (described in section 32 of the review) showed OSC effects while employing crossed hands to respond and responses with the feet [25, 198]. We did not assess such responses but based on their findings, we cannot rule out the abstract coding account [25]. Therefore, in our experiments, we could postulate that a handle oriented to the left does not certainly activate responses with a left hand (i.e. we can go against the action specificity account) [25]. In turn, the important variable would be the matching between attributes of the stimulus set and the actual response position (as opposed to the hand) [25, 183, 184]. These are the main findings of the second experiment by Phillips and Ward (2002) [25]. Still, in our experiments as well as their study, there could be another view of action specificity: it could be accurate that any affordance effect could rely more strongly on "location" i.e. the hand placed nearest to the item's handle could be the hand most suited to be afforded the action [25]. However, their third experiment (using foot responses described in section 32 of the review) rule out this interpretation and favor the abstract response coding view [25]. Indeed, they still showed an advantage for matching compared to non-matching trials [25]. Moreover, based on some other previous studies, in our experiments, we could postulate that the item's orientation which we have shown to make left- and right- hand responses easier [5, 37], could possibly be found to affect response choice executed with the index and middle fingers of one hand [1, 37]. For example, based on Vainio (2007), the response code generated in the orientation effect of our experiments would be rather abstract [1]. To sum up, based on findings such as those of Phillips and Ward (2002) as a whole, we can assume that at least some part of the abstract coding idea is accurate [25]. However, there is no definite clear answer in response to this matter given that the different studies described in the last few paragraphs show conflicting and contradictory findings.

Contrasting the prime objects that we employed to more abstract primes

Vainio (2011) (section 25 of the review) support the affordance view based on the NCE found in their first experiment for their mug prime [29]. In contrast, their novel prime and their arrow prime (i.e. abstract primes used in their second experiment which do not involve affordances) lead to PCEs [29]. The mug primes in Vainio (2011) as well as in the first experiment of Vainio (2014) are similar to our object primes since they involve affordances and give way to an NCE [26, 2]. On the other hand, according to studies described in section 25 of the review and Vainio (2014), abstract spatial features would give way to PCEs despite the abstract shape prime and the prime involving affordances having identical key spatial attributes [26, 29, 169, 279]. Both our experiments (as in Vainio (2014) for their actual mugs) involve the recognisability of the prime object stimuli and consequently that of the stimuli's handle affordance which allows us to observe NCEs [26, 29]. Thus, in our experiments, we can conclude that there are particular inhibition processes for the visuomotor treatment of handle affordances based on the fact that the NCE was generated by the handle information of our various real prime objects that can be recognised as such [26, 29]. In contrast, based on Vainio (2011), we can anticipate that the NCE would not be generated by abstract primes that would match the spatial features of our real prime objects [26, 29]. Vainio (2014) supports this account for their NMHP and we can in turn conclude, as in their study, that the affordance effects are distinct from effects due to abstract spatial features [26]. Hence, in both our experiments, the fact that we observed NCEs lends support tor the action specificity view (i.e. affordances) as opposed to abstract coding. Thus, our findings are not closely associated with the Simon effect since we did not use an abstract prime, our primes consisted of images of real objects with affordances and we demonstrated NCEs (not only positive priming)

[26]. Thus, we may propose that our handle affordance effect relies on neural processes that differ from other spatial priming effects [6, 26, 31, 180]. This account is supported by the fact that in Vainio (2014), mug primes have opposite behavioral and late LRP patterns compared to abstract primes [6, 26, 31, 180]. Their conclusions (in section 31 of the review) which explain the contrast between handle affordances and abstract shapes could also apply to both our experiments [26, 29].

<u>What could we expect if we had used animal stimuli?</u>

In both our experiments, we did not evaluate animal stimuli as a control. Our effects for manipulable prime objects could be: 1) particular to motor mechanisms or 2) caused by the relative location of item attributes that are visually salient [28, 166, 280]. The results in Witt (2010) (who contrasted manipulable objects to animals) support the former option and oppose the latter [28, 166]. In turn, in our experiment as well (although we did not utilize animal stimuli), if our effects are due to motor mechanisms, we could postulate that we would not find compatibility effects (neither PCE nor NCE) if we had utilized animals as prime objects since they are not manipulable [28, 166, 280]. In other words, if it is the motor simulations evoked by the prime objects that give way to the effects we found, those motor simulations would be limited to items that generate particular motor plans (such as the manipulable objects we employed as opposed to animal stimuli) [28]. Moreover, we could assume that treating animals would not employ motor knowledge, as proposed in other studies by the absence of activation in areas that are motor-related [28, 280].

<u>Contrasting the TEC view with a more general SRC effect</u>

Both our experiments may involve the TEC view (section 4 of the review) [27, 40-42]. Yet, as in Matheson (2014), it is possible that our potentiation effects could be best understood as low-level attentional effects (i.e. a more general SRC effect) as opposed to the ETC view [27]. This alternate interpretation was addressed in regards to our second experiment. That is, our potential PCE trends could be attributable to one of two notions (sections 48 and 50 of the review): 1) visual perception leading to the automatic activation of motor schemas (the ETC view) or 2) an attentional bias produced by the handles (a more general SRC effect due to the low-level attentional view) [27, 56, 166]. Matheson (section 40 of the review) evaluates both options by assessing the P1 [27, 50, 281]. Anderson (2002) (section 38 of the review) supports the low-level attentional view [27, 56]. In their experiment, the presence of an effect for clocks cannot be explained by the automatic activation of linked motor mechanisms since clocks aren't manipulable [27, 56]. Rather, their results show that their effect is generated by attentional mechanisms that have a bias for one spatial area of an item like handles of scissors or hands of clocks [1, 27, 50, 56]. This latter explanation may apply to our experiments and our items and other findings (in section 38 of the review) also support this explanation [1, 27, 50, 56]. Also, in Cho and Proctor (2010) (section 38 of the review), since the potentiation effects were shown when subjects used one single hand to respond, the potentiation effect could be caused by a more general SRC effect (which could also explain our potentiation effects) [27, 166]. Yet, as was pointed out elsewhere in the review and discussion, many studies didn't find alike effects when two hands were used to respond compared to two fingers of a single hand (but some studies like Cho and Proctor (2010) did) [27, 166].

Contrasting our experiments to the Matheson (2014) study

Our dot experiment is similar to Matheson (2014) (section 40 of the review). We also utilized target dots that are cued with regard to space by different attributes of items which are manipulable (the handle or the functional end) [27]. That is, the target dot can be seen either close to the handle side of the prime object or close to its functional end [27]. In our dot experiment, the cue (prime object) is also shown centrally with a right or left orientation and a black target dot was shown near the item's left or right side [27]. However, in both our experiments, the target and prime object are not shown simultaneously i.e. the prime disappears prior to the target [27]. Also, we utilized and assessed 8 prime-target SOAs where as in their experiment, they did not include SOAs in their analysis or results even though they used random time intervals for the duration of the cue [27]. In addition, we only utilized manipulable items (i.e. we did not use animal images as controls) [27].

Contrasting the TEC view and the low-level visual attention account based on Matheson (2014)

In section 40 of the review, we go over the electrophysiological (i.e. the assessment of P1 as an index of early visual attention) and behavioral findings of Matheson (2014) [27]. They end up opposing the ETC view and backing up the low-level visual attention account and, more specifically, that implicit visual attention has a bias for the artifact handles [27]. If we try to understand our own results according to the ETC view, we can understand our PCEs as being indicative of the automatic activation of motor schemas (i.e. an affordance activation due to the prime) and the NCEs as being indicative of the inhibition of that activation (i.e. an affordance inhibition due to the prime) [27]. On the other hand, according to the low-level visual attention account, we would understand our PCEs as being indicative of an automatic bias in implicit visual attention to the artifact handle and the NCEs as being indicative of that bias in implicit visual attention to the functional end or top component of the artifact [27]. In turn, although we did not assess the P1 ERP, if we base ourselves on Matheson (2014), we would support the latter account: visual attention renders manual responses quicker when the response hands and the salient item attributes (either the handle or top component/functional end) are compatible (i.e. in the same location in space) [1, 27, 50, 56, 164, 166]. Their P1 findings back up the behavioral results of other studies that propose this assumption [1, 27, 50, 56, 164, 166]. In our experiments, we could suggest that this partiality is automatic and occurs in earlier phases in the visual processing of an item (this is supported by their electrophysiological results) [27]. Yet, the fact that the direction of priming in our experiments is modulated by SOAs could be an argument in favor of the ETC view. Likewise to their proposition, we could also assume that a history of responses involving reaching and grasping manipulable items could augment the saliency of a specific part of the item, particularly the handle/graspable part [27]. To sum up, our findings could potentially be explained by either the affordance view (i.e. the ETC) or the low-level attentional view [56, 198, 219, 220].

Support for our effects involving motor mechanisms as opposed to perceptual mechanisms

Based on earlier research (sections 63 and 45 of the review), both our experiments would fit with the account that the NCEs (i.e. inverse priming effects) do not take place at perceptual levels (i.e. the NCE cannot be explained by a perceptual bias) or central semantic levels (like abstract left or right codes indicative of the side of response without being based on the response modality) but actually reflect response-associated processes evoked inside the motor system by our prime objects (several studies support this notion some of which are addressed in sections 15, 45 and 63 of the review) [8, 120, 121, 185, 97, 128-132, 107, 111, 116, 211-214]. Hence, as supported in other studies, it is likely that our NPEs are indicative of inhibition mechanisms of the visuomotor system (not perceptual mechanisms) [8, 33, 133]. In addition, we can suggest that our negative priming was shown to be a motor effect since any effects entirely linked to perception are in the reverse direction to the NCE [29, 33]. Also, although there are differences between both our experiments and Klapp and Hinkley (2002) (section 46 of the review), their conclusions may apply to our experiments: inverse priming occurs at the level of stimulus-response selection (as opposed to the level of perceptual processes) [111, 124]. Thus, based on their behavioral results, we may suggest a response-associated view of inverse priming effects and we can make alike conclusions as their study (section 47 of the review): inverse priming effects don't rely entirely on perceptual similarity between prime and target (such similarity is mostly absent in our experiments) [111, 124].

How does the "inhibition threshold" hypothesis fit with our experiments?

Despite both our experiments potentially somewhat involving endogenous inhibition to a greater extent than exogenous inhibition, a threshold mechanism involving perceptual sensitivity/strength (i.e. the 'inhibition threshold' hypothesis in section 14 of the review) could be implicated [8, 121, 123]. Indeed, although we did not intentionally modulate the prime's perceptual strength, we could postulate that when the perceptual strength of the primes would go down, NCEs (i.e. inhibition) would turn into PCEs (i.e. the lack of inhibition) [8, 123]. Likewise, if there is a rise in perceptual strength of the primes (above a given threshold), the PCEs would turn into NCEs [8, 123]. Eimer and Schlaghecken support these postulations by actually modulating perceptual strength [8, 123]. For example, according to the inhibitory threshold hypothesis, in our dot experiment, the results tend to a potential PCE trend at short SOAs (although this was not statistically significant) which may be indicative of the sensory strength of the prime being reduced leading to a lack of enough drive for the inhibitory process since the prime-target interval is too short [8, 119, 123, 138]. This assumption is mirrored by the fact that only when Eimer increased the prime-mask time interval did the PCEs turn into NCEs (section 14) [8, 123]. Indeed, in our dot experiment, the PCE also turned into NCE when we increased the prime-target interval (at long SOAs). Thus, the inhibition threshold hypothesis could apply to our experiments and fits with the findings in section 14 of the review: inhibition due to primes correlates with the primes' strength with respect to perception [8, 123]. Hence, in both our experiments where the subjects are conscious of the prime object, our observed NCEs could be indicative of the prime stimuli being adequately strong in terms of perception to rise above the hypothetical inhibition threshold and generate the inhibition in an automatic way of the motor activation linked with the primes [33, 121, 123]. Our potential PCE trends could imply that the perceptual strength of the primes is insufficient [33, 123, 282].

How does a hypothetical activation threshold fit with our experiments?

In terms of our experiments which involve motor activations evoked by affordances of items that are shown briefly and that are task-irrelevant, we may explain the automatic inhibition as an inevitable result of a motor activation that doesn't rise above a hypothetical activation threshold (not to be confused with the inhibition threshold) [29, 33, 107]. That is, in regards to our NCEs, we could propose based on the self-inhibition account that there was an inhibition of the activation since the activation did not rise above the required activation threshold potentially and in part because of the brief display of our prime [33, 107]. Vainio et al. (2011) make the same assumptions given that they found that a handle affordance of a briefly shown item is associated with negative priming [29, 33]. In both our experiments, in Vainio (2011) (described in section 25 of the review and earlier in the discussion) and in the BMP, the NCE may be linked to an alike motor inhibition process: this hypothetical activation threshold [8, 29, 107]. If this threshold of activation is not surpassed, we would get an NCE [29]. In contrast, when it is surpassed, we would get a PCE and the activation leads to the preparation and commencement (if it is suitable to the current overt behavior) of the action linked with the activation [8, 29, 107]. Hence, when stimuli are 'near-threshold', this will produce only incomplete activation which is processed by the motor system as an unwanted activation due to the fact that it may give way to an unwanted explicit behavior and, thus, it is instantly inhibited [29]. In turn, we would observe our NCEs and this does not allow preparation and commencement of the action linked with the activation [29]. Thus, it is necessary that motor activation generated by item affordances do not surpass the hypothetical activation threshold so as to see the inhibitory effect for brief items [29].

Contrasting our experiments to the Mattler study: our primes and targets are not perceptually alike

In our experiments as opposed to Mattler (2006), there is no obvious perceptual similarity (i.e. geometric likeness) between prime and target since the prime is an object (with affordances) and the target is an arrow or a dot (i.e. the prime and target have different forms as opposed to ,for instance, an experiment where they are both arrows) [111, 146]. Hence, unlike Lleras and Enns (2006), such perceptual similarity should not play an important role in our results: we could preclude a perceptual interaction between the attributes of prime and target [134, 146, 2177]. Indeed, as mentioned previously, we can instead support a motor account of inverse priming effects (like Klapp and Hinkley (2002) in sections 63 and 65 of the review) [111, 124].

Mattler (2006) compared: 1) the effects of primes and targets that are perceptually similar with 2) the effects of primes that are dissimilar but congruent or incongruent with the target [92, 111, 113, 116]. We only assessed the latter option [111]. The first element in the findings of Mattler's first experiment (section 47) is that the priming effect is attributable to the fact that the perceptual treatment of the target is rendered easier when the prime and target are perceptually alike [111]. Although our experiments do not preclude this conclusion, we could argue that this similarity would not be the only factor that could influence the priming effects [111]. Indeed, the second element of target priming effects of Mattler's first experiment (which does not involve facilitated perceptual treatment of the target) applies to our experiments: congruent primes (that are perceptually different from targets) gave way to responses which were facilitated in contrast to incongruent primes [111]. This effect (reflected in our potential PCE trends) implies that target priming effects can't be reduced completely to the fact that the prime and the target perceptually interact and this effect seems to occur at more advanced phases of processing that are not impacted by perceptual similarity [111]. Hence, based on other studies. we could propose that our target priming effect may occur at the level of the response system [111, 116, 213].

Our results of in terms of NCEs demonstrates that the inverse priming does not depend on the prime and target being similar [111]. Hence, we conclude that: 1) prime congruency strongly impacted the inverse priming effect, 2) inverse target priming effects are not always entirely due to the fact that prime, mask (which we did not use but is common in other studies) and target stimuli perceptually interact (although this can not be ruled out according to other research [111, 214, 217]) and 3) inverse priming effects can't fully occur at stages implicating perception [140]. Our conclusions stand in contrast to: 1) some of those in Mattler's first experiment in terms of inverse priming effects and 2) several studies (section 47) where there was a lack of or a reduction in inverse priming effects for distinct primes and targets [107, 111, 185, 215]. However, likewise to our findings, several studies (section 47) found inverse priming effects for distinct primes and targets [111, 120, 124, 215]. As a side note, if we consider that there may be some kind of perceptual similarity between our primes and targets (although unlikely), then we may suggest that our inverse target priming effects are somewhat influenced by this similarity [111].

<u>Two types of inverse priming effects: our effects involve the NCE-NP rather than the NCE-P</u>

Based on Mattler (2006), there are two types of inverse priming effects (section 48 of the review) where 1) it does not depend on similarity between primes and targets or 2) it does [111, 216]. Our NCEs are more likely to be the non-perceptual type of inverse priming effects (NCE-NP) rather than the NCE-P (the perceptual type of inverse priming) since our NCEs do not depend on perceptual similarity between stimuli [111, 216-218]. Yet, although we do postulate that our NCE is more similar to the NCE-NP, an important distinction is that the prime visibility is not decreased since our prime objects remain completely visible (we did not use a mask to reduce prime perceptibility) and, yet, we still observe an NCE [111, 124, 135, 140, 216-218]. That is, the decreased visibility is not a necessary condition for our NCE-NP (likewise to most positive priming effects) and the NCE does not disappear with greater prime visibility [111, 113, 116. 216-218]. This may be due to the fact that our inhibition does not rely on a mask and may have other causal processes. Note that the NCE-P also does not depend on prime visibility [111, 216-218]. Also, since our results may be linked to the NCE-NP, we could postulate a motor property to our kind of inverse priming (which is backed up by the fact that our primes generate action affordances) as opposed to the NCE-P which would support a non-motor property for inverse priming [111, 216-218].

How our effects fit with the self-inhibition account

As suggested in other studies (such as those involving the NMHP), both our experiments can fit with the self-inhibition account of the NCE: there is an automatic rapid motor activation by a prime of the corresponding hand prior to the generation of an inhibition that goes against the previous initial activation [2, 26, 107, 119, 123, 134, 135, 143]. That is, in our dot experiment we have a behavioral pattern involving sequential phases of automatic activation before inhibition which is thought of as a common attribute of low-level motor control in which the initial motor activations evoked by primes self-inhibit in an active way in cases where they are no longer backed up by perceptual support [123, 134, 283]. The associated processes described in section 15 of the review apply closely to our dot experiment despite the lack of a mask. As in other studies (some of which used masked primes), our arrow experiment may also support these sequential phases [8, 107, 120, 121, 123, 134, 136, 145, 283], although we don't observe the activation (prior to inhibition) in our behavioral results. Yet, both our experiments do not meet the second condition (stated in section 15) for the self-inhibition model i.e. we did not use a mask and hence the masks cannot immediately block the sensory support of the prime [119, 135]. However, previously in this discussion, we proposed a potential logic (which differed between our dot and arrow experiments) to our findings which could explain how our findings and NCEs could still fit with the self-inhibition model despite the lack of an effective mask [119, 134, 135].

According to some studies (section 15), the NCE (in terms of self-inhibition) implicates the subsequent factors: 1) prime items that are similar to target items give way to the activation of matching motor responses, 2) this activation is automatically self-inhibited when the perceptual support for the prime goes away and 3) self-inhibition happens only when the prime strength is high enough to produce this inhibitory mechanism i.e. the “inhibitory threshold hypothesis” [123, 134, 146, 119, 135]. In both our experiments, the first argument is not backed up by our findings since our primes and target arrows/ dots are not similar. However, as explained earlier in this discussion, the second and third argument make sense with our experiments [146, 134, 119].

The impact of prime visibility

According to previous research, NCEs are typically linked to subliminal primes (without conscious awareness i.e. not visible) where as PCEs are linked to suprathreshold primes (not masked and more visible) [8, 124, 135, 146]. However, likewise to other studies, we can assume that prime visibility is not a sole indicator of priming direction since we kept prime visibility constant (the subject should in all cases be equally conscious of the prime and we did not have to assess a prime identification task) and observed both potential PCEs as well as NCEs [134, 146, 217]. Hence, as in other studies, in our experiments, inverse priming and positive priming could have in common the feature that they do not depend on prime consciousness with respect to vision [111, 113, 116]. However, as opposed to other studies [92, 111-118, 139], we did not directly assess the influence of the consciousness of our primes on the effects since this was kept constant [92, 111, 113, 116]. Also, we can assume that the strength of priming is not solely regulated by prime visibility since it fluctuates when our prime visibility is kept constant [134, 146, 217]. This is shown by other studies: there is no connection between the magnitude of priming and prime visibility [134, 146, 217]. Also, as in other studies, we can postulate that there is no direct connection between low prime visibility and the NCE since we observe NCEs without masks and when the prime object is clearly visible [146, 218, 217, 111, 140, 113, 116]. In fact, the prime strength is not indexed by prime visibility which implies that prime visibility is not involved in the inhibition threshold hypothesis [123, 134, 146, 217]. Thus, as in previous studies, we may assume that inverse priming effects may not be impacted by how easily subjects identify the primes [111, 140].

Why do we have different findings for our dot and arrow experiments?

Target dots involve location were as target arrows do not

Research about the Simon effect (described in review) involve abstract location codes [11, 38, 60, 284]. Our effects for both our experiments differ from common Simon effects since we assess the effect of the prime object orientation (which involves affordances and a reach-to-grasp response) as opposed to the effect of stimuli location (i.e. the important stimulus–response association is not spatial location) [5, 11, 21, 25, 38, 60, 63, 64, 284]. That is, our prime object is always presented centrally such that object location does not impact on the orientation factor. However, in our dot experiment, since the target dot varies in its location to the left or right of the screen, our effects may involve abstract location codes that the target location produces automatically [11, 38]. In contrast, given that both the target arrows and the prime objects are showed centrally in the arrow experiment, it is less likely that the effects found in this experiment are related to the notion of abstract location codes which the target location produces automatically [11, 38]. In fact, this could be one of the reasons that explain the different findings between both our experiments. In support of these postulations and as mentioned earlier, the time course of our effects in our dot experiment fits more closely with that of the Simon task (which also involves location) where as the time course of our effects in our arrow experiment fits more closely with that of the first experiment of Phillips and Ward [25, 38]. Hence, our dot experiment could be abstract in a similar way to the Simon task [25]. However, despite the fact that the time course of our effects in our arrow experiment proposes that the response activation is not equivalent in a direct manner to a Simon-type activation, it could still be abstract in a likewise manner (Phillips and Ward made this same conclusion) [25]. For instance, a left-pointing handle could evoke a generalized "left" code, making all kinds of responses in the direction of the left side of the surrounding easier [25, 5].

The dot experiment is more likely to involve a segmentation effect than the arrow experiment

One view of our findings, consistent with those of Tucker and Ellis (1998) [5], is that segmentation in terms of perception could give way to the handle on its own serving as a lateralized stimulus (this is also proposed by Phillips and Ward (2002)) [25]. If this is the case, the handle in the prime picture could generate response activation alike to that of lateralized items in the Simon methodology [25]. Yet, Phillips and Ward (2002) do not presume this is a probable view for their correspondence effects since their time course evidently differentiates their correspondence effects from those in the Simon effect [25, 172, 277]. As explained previously, the correspondence effect lasting for a long amount of time and increasing progressively in the experiments by Phillips and Ward (2002) opposes the temporary response activation observed by lateralized stimuli in the Simon methodology [25]. The time course of our dot experiment fits with the temporary response activation observed by lateralized stimuli in the Simon task (and the time course differs from that of Phillips and Ward). Hence, we may conclude that in the dot experiment, the handle on its own could be serving as a lateralized stimulus. In contrast, the time course in our arrow experiment fits with that of Phillips and Ward and, thus, we can not make a similar conclusion. In fact, in our dot experiment, we could suggest that the segmentation effect is given more importance since this experiment involves the subject making a response in regards to the location of the lateralized target dot. In contrast, a central target arrow involves shape or form as opposed to location. Thus, this could account for the differing findings between our dot and arrow experiments.

Arrow targets are central where as dot targets are peripheral

In our arrow experiment the target is central where as in our dot experiment the target is presented laterally which could have led to different findings between our two experiments given that peripheral vs central primes also lead to different findings in previous studies [8, 121, 123, 142]. Some experiments (section 47 of the review) also mirror our different findings due to this distinction [111, 121, 185]. Hence, based on the 'central-peripheral asymmetry' described prior in the discussion and review, it is possible that the different results between both our experiments may also involve differences in perceptual sensitivity in regards to our targets [8, 121, 123, 142].

The impact of attentional orienting in the arrow experiment as opposed to the dot experiment

In our arrow experiment, we used the target arrow which includes implied information regarding direction (we did not use another shape) [37, 88, 285]. In turn, attentional orienting could play a role in our arrow experiment. Indeed, previous studies show that an arrow's pointing direction has the ability to give way to an automatic and immediate (i.e. reflexive and not volitional) attentional orienting to its direction [37, 88, 285]. In other words, a cue that is central and that involves direction (such as our target arrows) can evoke a reflexive attentional shift [37, 88, 285]. In our dot experiment, since we used lateralized target dots, the subjects do not respond to shape, the target dots do not involve direction and they are not centrally displayed. Hence, the target dots can not lead to this attentional orienting. Importantly, these postulations regarding target arrows leading to attentional orienting may play a role in the different results between our two experiments. However, in their third experiment, since Vainio and Mustonen (2011) reproduce the results with the target arrow of their first experiment by employing another shape without implied information regarding direction (a C or a mirror C i.e. a target stimulus that involves shape and that is not known to generate an automatic attentional orienting), we could potentially reproduce the results of our arrow experiment with a similar shape [37]. Hence, their study shows that the attentional orienting of the target arrow is not a key component of their first experiment's SRC effects, so we may postulate the same argument for our arrow experiment [37]. However, given differences in our findings between our two experiments, in our case, we cannot rule out that the target arrows we used could give way to attentional orienting contributing to the different findings.

<u>A form-treatment pathway (arrow experiment) vs a pathway involving location (dot experiment)</u>

Earlier in the discussion (the section entitled **"**Another impact of employing several distinct prime objects" based on section 29 of the review), we described differences between Vainio, Ellis and Tucker (2007) and Phillips and Ward (2002) in terms of the temporal features of their orientation effect [1, 25]. A second argument that could explain this contradiction involves the difference between a form-treatment pathway (such as for our arrow targets) and other pathways (such as color pathways or the pathway employed in our dot experiment involving the location of the dot as opposed to form) [1, 25]. In other words, this argument for explaining the contradiction between Vainio, Ellis and Tucker (2007) and Phillips and Ward (2002) is that the orientation effect may progress distinctly relying on the fact that a colour or form pathway (respectively) is required for treating pertinent target information [1, 25]. Indeed, when studies used targets that required shape discrimination (such as arrows) in contrast to targets involving lateral signals to the left or right (which require a discrimination based on location), they found differing results [111, 121, 185].

In our dot experiment, the target parameter does not involve color or form but rather location [1]. Based on previous research, it is likely that mechanisms involving a form-treatment pathway, which we can postulate to be necessary to treat the orientation information of our prime, would be suppressed when the task necessitates focusing on lateral dot location information (or target colour in previous research) obstructing access to the affordance information of the prime [1, 286]. In other words, this suppression may block continuous availability to affordance information [1]. In contrast to our dot experiment, in our arrow experiment, the form processing pathway is required for treating pertinent target information [1]. This may account for differing results between our two experiments. The fact that some distinctions in the tasks (mainly the target involving colour vs shape) between studies by Ottoboni et al. (2005) (section 27 of the review) and Vainio and Mustonen (2011) led to different results also supports some of the above postulations [37, 170]. However, despite the fact that some suppression of mechanisms related to form could take place in a task involving colour discrimination, the findings of the first experiment by Vainio, Ellis and Tucker (2007) demonstrate that this suppression did not block the temporary treatment of affordance information briefly following the sudden start of the prime display [1].

The differing findings in our experiments may also involve distinctions in regards to semantic effects. Indeed, based on research by Humphreys and Boucart (1997), we could postulate that semantic features of items (that do not require an endogenous focus of attention) affected task execution to a greater extent in cases where the subjects had to concentrate on target form (like in our arrow experiment as opposed to our dot experiment) [1, 286]. In fact, these authors demonstrated in a task involving colour-matching, that there was a lack of semantic effect [1, 286]. Also, they proposed that form processing pathways, which are assumed to be required for treating semantic item information, are not suppressed when the task requires treatment of target form information (as in our arrow experiment) [1, 286]. Thus, according to earlier studies, in our dot experiment, given that the task does not involve target form, there may be a lack of semantic effects [1, 286]. In turn, the priming effects linked with semantic and form features of the prime can be reduced or removed when the task requires treatment of the target dot's lateral location (or in their experiment, target color) and not target form [37, 286]. To sum up, in our arrow experiment, both prime object and target arrow share a shape/form attribute where as, in the dot experiment, the target dot only has a location attribute and the location of the prime does not vary. Hence, the possibility remains that this distinction may account for the different findings due to: 1) a different degree of suppression of mechanisms (involving a form-treatment pathway) necessary to treat the prime object orientation information, 2) a differing availability to affordance information and 3) the presence or lack of a semantic effect [1, 286]. In other words, in our dot experiment, the orientation effect decreased with rising SOA in a similar direction to Vainio (2007) (which involves target colour) and as opposed to Phillips and Ward (2002) (which involves target form) [1, 25]. In contrast, in our arrow experiment, the results move in a similar direction (i.e. from an

NCE towards a PCE) to those of Phillips and Ward (2002) that demonstrated that the orientation effect which is found for task-irrelevant items, progresses steadily in cases where the task necessitates form discrimination (such as that of an arrow) [1, 25].

Also, it may necessitate a substantially lower degree of cognitive resources to make the response hand choice in terms of our arrow direction in contrast to our dot location [37]. Indeed, Vainio and Mustonen (2011) also state that it may necessitate a substantially lower degree of cognitive resources to make the response hand choice in terms of the letter C orientation (as a target) in contrast to a target's colour (as in Ottoboni et al. (2005)) [37, 170]. Both studies are described in sections 33 and 34 of the review [37, 170]. A task involving the letter C (or our arrow target) could be executed in an overt and quick manner necessitating a small amount of working memory in contrast to a task where response hand choice occurs in regards to color (or dot location) [37]. In our arrow experiment where the target arrow involves shape or form likewise to the targets of Vainio and Mustonen (2011), their finding is mirrored by our strong NCEs (already present at the shortest SOA) potentially since the mechanisms implicated in mapping of prime orientation could take place more quickly (compared to the dot experiment) [37, 170]. Similarly to Ottoboni et al. (2005), the more challenging task in our dot experiment could have deferred the mapping of prime orientation which could explain why we only started observing NCEs at longer SOAs [37, 170]. Thus, subjects may respond to our arrows and dots with distinct time courses and speed.

Also, the differing results in some experiments (section 47 of the review) may be due to the primes and targets being similar (both arrows) or dissimilar constructs (like a prime arrow and a lateral target) [111, 121, 185, 215]. In turn, the option remains that in one of both our experiments, the primes and targets may be somehow more alike to one another than in the other experiment, in turn leading to different results.

<u>Prime and target are at the same location in the arrow experiment and at different locations in the dot experiment</u>

In our arrow experiment, prime and target are displayed at the same location in space (they were always displayed at fixation and we told subjects to focus on the center of the screen despite the lack of a fixation point). In our dot experiment, prime and target are not displayed at the same location. This may account for distinct results in both our experiments. As a general example of the importance of an identical or distinct location between prime and target, Lleras and Enns (2005) proposes that NCEs could be indicative of processes involving attention or perception which are generated when prime and target take place at an identical position (such as negative priming or repetition blindness) as opposed to motor inhibition [134, 218]. Furthermore, in terms of our experiments more specifically, we cannot rule out the repeated location advantage which is indicative of the notion that priming is more successful when prime and target are displayed in identical or close positions [146, 169, 287, 288]. Properties taking place in spatial positions nearer to the target will typically lead the subjects to see them as more task-pertinent [146]. Also, the nearer physical stimuli are to one another, the more likely the visual system will assess them as distinct instances of one individual item developing through time [146]. Thus, the above postulations may partly account for the distinct results between both our experiments. For instance, the fact that we saw NCEs at short SOAs in the arrow experiment where as it required long SOAs to observe NCEs in the dot experiment could be due to a more successful priming in the former.

Also, we could attribute the different results between our experiments to the fact that technically in the dot experiment, the target is never at the cued position of the prime and in our arrow experiment, the target is always at the cued position of the prime [1]. In turn, this could account for the fact that the NCE in the arrow experiment was seen at short SOAs (i.e. more quickly) than the NCE in the dot experiment which only appeared at longer SOAs (i.e. more slowly). For instance, if the cue is displayed at the position of the target before target display, the target is recognised and discriminated more quickly compared to the case where the target position is not preceded by a cue before target display [1, 169]. Perceptual mechanisms are made easier in the cued position since in the case where the target is displayed at the cued position briefly after the disappearance of the cue, attention stays allocated to the cue position [1].

A limitation: how the affordance account we demonstrated for orientation could differ from PPAs

In both our experiments, we show that item orientation is a potential source of affordance [198]. Symes, Ellis and Tucker evaluates this potential source of affordance and looks at whether item orientation is an item attribute that could play the role of a 'pure physical affordance' (defined in section 49 of the review) [198]. They end up backing up the existence of PPAs with respect to item orientation by using carefully chosen stimuli [198]. Visual stimuli utilized in earlier studies and maybe in our experiments (we employed images of objects which were oriented, 3D, meaningful and non-abstract) could have led to a confusion between orientation (involving motor affordance effects) and sources of affordances implicating semantics and attentional partiality [198]. Thus, although our experiments support the affordance view, it is possible that attributes with respect to semantics and attention do not permit our experiment to argue in favor of PPAs [198].

Firstly, we could suggest that both our experiments do not back up PPAs due to the semantic aspect: 1) our stimuli were mainly common household items that have clear implications for actions, 2) they are not novel and 3) they are not neutral with respect to function (they have features with respect to function such as handles) [198]. Symes, Ellis and Tucker make the same suggestion in regards to experiments in earlier studies [198]. As some investigators suggest, in our experiments, picking up an item by its handle accurately may require an interaction between cognition and action [198, 177]. Thus, as stated in section 49 of the review according to other studies, in both our experiments, the effects can be caused by the item's affordance with respect to function and semantics to a comparable extent as potential PPAs [198]. That is, as opposed to the OSC conditions established in Symes, Ellis and Tucker, the item orientation effects cannot be considered PPAs [198]. Also, as stated in other studies, it is likely that the participant's goal and the task characteristics also offered an action-related implication to our prime items [22, 39, 198].

Secondly, as in other affordance experiments, both our experiments have evaluated items that are mostly visually asymmetrical [56, 198]. Likewise to what these other investigators suggested (and as explained in section 49 of the review), in our experiments, it is likely for visual asymmetry to produce an attentional bias in favor of the attribute of the prime object that has significant saliency, and consequently this bias (which implicates a movement of attention to a specific position of the item) is the reason for the generation of motor signals [198, 219, 220]. In other words, our experiments did not include a control for areas with significant saliency i.e. there could be areas or features with significant saliency that attention could be focused on [198, 56]. Thus, it is possible that our findings are due to the attention-directing account (described in the review) [56, 198]. In turn, similarly to the third experiment of Symes, Ellis and Tucker, we did not isolate affordance from attention [198]. We should note that some of our prime objects (such as the ruler and the fondue fork) *approached* symmetry but they were not truly entirely symmetrical. Hence, in this discussion, we consider that all of our prime objects were technically asymmetrical.

How the effects in our experiments could differ from effects due to PPAs

When using visual stimuli with a control for factors of semantics and attention, Symes, Ellis and

Tucker (section 50 of the review) did not demonstrate the same trend of results (in terms of time course) to that of Phillips & Ward (2002) which did not control for these factors [25, 198]. Based on this distinction, we could postulate that, if we had controlled for these two factors (which we did not), we also may not have found an alike pattern of results to the ones showed in the absence of these controls [25, 198]. Hence, likewise to the assumption made by Symes, Ellis and Tucker, we suggest that the temporal features of OSC effects generated to some extent from semantic connections between the objects and actions (such as in our experiments) are not the same as the temporal features of OSC effects generated from PPAs [198, 25]. Moreover, in contrast to our results and Phillips & Ward (2002), Symes, Ellis and Tucker demonstrated that across all their experiments, their SOAs (section 50 of the review) did not impact the OSC effect [25, 198]. Also, they mostly showed (with exceptions) that the orientation angle renders easier responses that are spatially compatible [198]. This is analogous to the potential PCE trends of both our experiments and their finding stands in contrast to our NCEs [198]. Thus, based on differences between our findings and those of their first experiment, we cannot conclude that the prime orientation only gives way to affordances in a quite abstract manner that doesn't directly impact action preparation (i.e. the affordance may not be abstract and could directly impact action preparation) [198].

<u>Our OSC effects may be better explained by an affordance-linked account (i.e. PPAs) than by the attentional partiality view</u>

As opposed to Symes, Ellis and Tucker, we did not compare images of objects that were symmetrical to images that were asymmetrical but we would expect stronger OSC effects for the latter (as in their findings) [198]. We found OSC effects for our asymmetrical prime objects but, based on their fourth experiment, we postulate that we would not find these OSC effects (or we would find weaker OSC effects) if we had utilized symmetrical prime objects (which we did not) [198]. Our prime objects were asymmetrical which means we could not remove the option of attentional partiality [198]. Their fifth experiment (section 52 of the review) used a detection task and demonstrates that the OSC effects for asymmetrical cylinders are better accounted for by the PPA than by the attentional partiality view [198]. Hence, based on their result, we could also postulate that our findings may not be due to attentional biases but rather our OSC effects are produced by motor affordances of a prime object's orientation [198]. In other words, if we base ourselves on their conclusions, we postulate that the end of the prime object with significant saliency does not appear to have an attentional bias to any considerable extent (as they demonstrated for their cylinder stimuli) [198]. Thus, we can back up an affordance-linked view as in their study as a whole which suggested this account in explaining the different trends of OSC effects demonstrated when employing items that were gradually modulated in regards to their visual complexity [198]. As a side note, their detection task has similarities to our experiments but there are significant differences [198]. Their data all together, support their key hypothesis that there are PPAs involving object orientation and the PPAs could at least partly play a role in our affordance effects [198]. To sum up, likewise to their study, our item's orientation seems to produce affordances that can be behaviorally demonstrated by proxy of our OSC effects [198].

<u>The impact of the position and distance (i.e. reaching space) of the prime in terms of orientation</u>

Our prime object is an image displayed on the screen such that it is technically within reaching space. Hence, we could not determine whether the compatibility effects are identical when the object is shown outside the reaching space [11]. Yet, Tucker and Ellis (2001) (which assesses grip type) found this to be the case and concluded that the compatibility effect does not rely on the item literally giving way to the affordance of an immediate action of reach and grasp [11, 289, 290]. Hence, based on their results, we postulate that the effect does not rely on the item being displayed inside the reaching space [11]. However, they explain that position and distance should not influence the type of grip that an item affords but the orientation of the reaching action (which we assess in our experiments) is a more transient affordance that may be affected by position and distance [11]. This is backed up by studies that demonstrate that item affordances differ with respect to whether the assessed attributes of the item are intrinsic (like grip type) or extrinsic (like orientation which is an attribute that depends on the subject) [11, 74, 157].

<u>Our experiments do not involve actual physical responses to the objects</u>

It is not expected that our effects would depend on the response actually being physically likely since our objects are not really being grasped and are merely images on a screen [11]. This is supported by some experiments in Tucker and Ellis (2001) and Tucker & Ellis, (1998) who found that: 1) the effect is shown when the items are not within reach and 2) when exclusively images (i.e. not real items) are employed [5, 11]. Hence, as in Tucker and Ellis (2001), rather than the effect being produced by the potentiation of a whole action, we suggest that our effect is evoked by more general representational mechanisms that represent item attributes in motor terms, and that it is this representation which relies on visuomotor activity, that evokes the effect [11]. Hence, as in Tucker and Ellis (2001), there is a distinction between an item actually priming a specific response in contrast to integrating motor components into its illustration [11].

The impact of the precise state of the individual

As in Tucker and Ellis (1998), all our affordance effects involve an identical precise state of the individual such that not all actions that can be executed toward the prime object in general can be executed in regards to that item given this precise state [5]. Also, as in other studies, we could postulate that it is the relative (not the absolute) location of the responses with respect to the items that is important [5, 188]. Also, as mentioned previously in the discussion and as in some studies, it is possible that demonstrating SRC effects in our experiments relies on the position of response location as opposed to the position of the effectors utilized to complete the responses [5, 182]. In contrast, based on Tucker and Ellis (1998), we propose that the key characteristic may be the connection between item orientation and the hands as opposed to simply the set up of the response keys to the left or right [5]. In section 41 of review is an explanation (relevant to our experiments) of the importance of the set up of the visuomotor system, the left-right effector systems and the left-right physical set up of the human body in compatibility effects and left-right coding [5].

A design limitation

Finally, a limitation to experiments 3 and 4 may be that a mixed design with a randomized order of different SOAs could have been better suited than a block design for SOAs.

XI. CONCLUSION

The two last experiments (“arrow” and “dot”) assess the inhibition of affordances. In turn, we can extrapolate the results to the study of schizophrenic patients. In such patients, symptoms such as delusions or false beliefs could be the result of an inability to inhibit representations that are irrelevant to a given situation. Hence, we may extrapolate the inhibition of affordances to the inhibition of representations linked with delusions or false beliefs. Thus, an option for future studies is to carry out the “arrow” and “dot” experiment with schizophrenic patients and compare them to healthy subjects. The expected result would be a reduction in inhibition (which might be interpreted for example as a lower NCE) in schizophrenic patients compared to healthy subjects. In fact, in a study by Frith, the authors state that "the positive and negative symptoms of schizophrenia reflect impairments in the perception and initiation of action" [291].

XII. REFERENCES

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