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The Potentiation Effect of Grasping Behaviors: Coding and Simulation Processes Operating Simultaneously

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Abstract

The motor potentiation effect of grasping behaviors, namely the fact that the mere perception of agrasping object facilitates compatible motor response. According to the simulationnist account [1], ata conceptual level, there would be an involvement of motor processes, which will produce motor simulation. However, the size coding account [2]. Suggest that effect could be due to a compatibility of size codes associated with stimuli and responses. Our go alistotest the automatic nature of the simulations with the Linguistic stimuli. Given that a potentiation effect is difficult to obtain with words, it is possible. That presenting them embedded in a sentence with an action verb could induce a motor simulation. For that, we conducted two experiments. In the first one, we presented verbs (i.e., TOSEE, TOGRASP) and non-word (EXLER) as control condition, just before displaying an object name. Participants were instructed to perform either a precision or power-grip according to the color. The result of the first experiment does not reveal a potentiation effect. Furthermore, verbs donot modulate effect contrary to the simulationnist account prediction. In our second experiment, we used pictures representing objects in real size instead of words. This time, the effect was obtained. It seems that when the object size is available, the effect occurs in line with the size coding account. In addition, the verbs modulate the effect. We observe the effect for power-grip, while for precision-grip only for (EXLER) a matter that is not consistent with the size coding count which doesnot predict verb modulation. Given that the precision-grip is more related to knowledge, it is conceivable that following the perception of verbs there is an activation of the motor system by mobilizing this precision-grip. Thus, this mobilization disrupts the process of coding the visual size of picture specifically for this response. Nevertheless, this activation could be partial, which could explain why no influence of these verbs was observed during our first experiment. So, the fact that there is this moderation of verbs suggests that it is possible that the coding process is implemented in parallel with the simulation process.

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Introduction

The nature of knowledge remains a great matter of debate in Cognitive Sciences. According to the embodied approach of cognition, cognition would not be independent of perception and motor skills [3]. Knowledge or concepts in this view would involve sensorimotor processes. Even more so, the sensorimotor features associated to the concept of "APPLE" (e.g., rounded, sweet, tart, red or green, usually grasped with a powergrip) would be represented in asensorimotor format as the one used at asensorimotor level. For instance, the conceptualization of an apple would involve visual processes like those used to perceive the color of the apple. Similarly, the actions associated with the apple (e.g., can be grasped with the hand, can be eaten) would involve the motor system [4]. A particularly influential theory developed in an embodied approach of cognition argue that to conceptualize object, it would be essential to simulate the features of previous experiences associated with the represented object, people, or event, especially by using sensorimotor processes [1,5,6].

This sensorimotor simulation theory consists of three major phases. First, when a physical entity or event is perceived, it will be represented thanks to feature detect or sactivated in the primary sensory are as for each sensory modality [3]. Accordingly, a neural state of activation occurs simultaneously in all sensory modalities (e.g., vision, taste, smell, touch, and hearing). Importantly, this neuronal state will encompass the actions carried out. It is argued that this neuronal state will be then captured by associative neurons located in adjacent areas. Following various encountering with the same object (e.g., various apples) and the capture of each independent neuronal state occurring, a simulator will be constructed, which is amore complexneural network that represents all components of ourprevious experiences with the object. A simulator is not seen as a static representation of acategory but rather like a generator of representations. Thanks to the simulators, a simulation process can then take place. Following the perception of an object, apartial neuronal state occurs (e.g., merevision of an Apple induces a neuronal state into visual areas). After such apartial activation, a process of Pattern completion occurs, which led to the activation of the entire network. This happens because the different parts of the net work are strongly inter connected and therefore the simple activation of a small part of the net work conducted to ignite the entire network. Therefore, the features of the objects extracted from previous encountering and that are not actually perceived will be automatically simulated. It is critical to note that the simulation doesnot solely encompass visual features (e.g., size), or more largely perceptual features, but also features of actions that are usually performed (e.g., the specific grasp) with the target object [5]. [7] reported data supporting this view. In their experiment, they presented pictures of objects usually requiring either a powergrip or a precision grip to be grasped. Thanks to a specific response device, participants must actually carry out either a precision grip or a power grip according to the semantic category of objects (i.e., natural vs artificial). Results showed faster precision grip responses when participants saw small objects associated with a precision grip (e.g., acherry) compared to larger objects associated with a powergrip (e.g., anapple). Conversely, power grip responses were faster when participants saw large rather than small objects. This effect, called the potentiation effect of grasping behaviors, is interpreted as the following. Merely seeing an object induces the automatic simulation of previous experiences associated with the object that include some a motor component about the usual grasp used to grasp the object. Such a component would inturn potentiate acompatible response [8,9,10].

Although this effect is well explained by the simulation account, an alternative hypothesis has been developed and supported. In this view, the potentiation effect of grasping behaviors could be rather due to alow-level visual feature of the presented objects rather than to the usualaction associated to them. Indeed, in the original study of Ellis and Tucker (2000), as well as in the multiple replications of this effect [11,12,7,13,14], objects differed according to their visual size. More specifically, objects associated with a powergrip (e.g., apple) were presented in a larger visual size than objects associated with a precision grip (e.g., strawberry). More precisely, the visual size use disclose to the actual size of objects in everyday life. Thus, it could be argued that object associated with a powergrip could be coded as "large" and objects associated with a precision grip as "small" because of their visual size. The same reasoning could be applied to the responses. Because power grip responses were performed on a larger switch than precision grip responses, both responses could be coded as "large" and "small", respectively.

Accordingly, the potentiation effect could be due to the compatibility/non-compatibility between size codes associated with stimuli and responses rather than because of the simulation of a motor trace. This size-coding hypothesis was first advocated by Miles and Proctor (2014) and Masson (2015) and have recently gained empirical support [15,16].

Recently, an alternative explanation of the potentiation effect has been proposed [2,18]. The potentiation effect of grasping behaviors could be rather due to alow-level visual feature of the presented objects rather than to the usual action associated as the size coding account suggests. Indeed, in the original study of Ellis and Tucker (2000), as well as in the multiple replications of this effect [11,12,13,14,15,16,7], objects differed according to their visual size. Accordingly, the potentiation effect could be due to the compatibility /non-compatibility between size codes associated to stimuli and responses rather than to the simulation of a motor component. More specifically, objects associated to a powergrip (e.g., apple) were presented in a larger visual size than objects associated to a precision grip (e.g., strawberry). Usually, the visual size is close to the actual size of objects in everyday life. It could thus be argued that object associated to a power-grip could be coded as "large" and objects associated to a precision grip as "small". The same reasoning could be applied to both responses. Because power grip were performed on a larger switch than precision grip, both responses could be coded as "large" and "small", respectively.

We recently conducted three experiments bringing an important piece of information in the context of the potentiation effect of grasping behavior [16]. In our first experiment, we inter mixed pictures and words which represent the same fruits and vegetables either associated with a precision grip or a powergrip (e.g., a cherry vs. an apple). In each trial, a fixation cross first appeared followed by the picture or the name of an object. The pictures were first displayed in grayscale and words in black. Then, either the picture or the word was colored in blue or orange. According to the color, the participant had to perform either a power grip or a precision grip. A potentiation effect has been observed for both pictures and words. In a second experiment, we used the exact same protocol except that the picture representing large and small objects, respectively associated with a power grip and a precision grip was no longer presented in a visual size corresponding to their actual size. Thus, all pictures were presented in the same visual size. This time, we did not find any potentiation effect neither for pictures nor for words. This last result supports the possibility that the potentiation effect reported with the words in our first experiment, depended actually on the visual size in which the pictures were presented. Moreover, in our third experiment, we solely presented words of graspable objects without any pictures. In this case, we did not observe any potentiation effect. We interpreted these results with the size coding account. Indeed, the potentiation effect for pictures presented in a visual size corresponding to their actual size is easy to interpret by a sizecoding approach unlike the effect obtained on words. We have explained that the effect reported with the words could be due to the fact, that the size codes associated to pictures have been transferred towords. Thereby, when, pictures did not differ according to their visualsize, the transfer of size code cannot occur and thus, there is nolonger effect on words.

It is note worthy that our results [16] are not in line with the ones reported by [13]. Indeed, they were able to find a potentiation effect with words denoting manipulable objects that are not presented inter mixed with pictures of these objects. One major difference relies on the task used. Unlike Tucker and Ellis (2004), we did not use a semantic categorization task but rather a chromatic categorization task. The main difference between both tasks could be that the chromatic categorization task did not explicitly require the access to the conceptual representation of the object while it is necessary to achieve the semantic categorization task. Therefore, it is possible that a simulation process can beat work when words are read but only if a conceptual access is required by the task at hand. Therefore, it seems that the simulation processes unlike the coding process is less automatic than original advocated [1].

Therefore, in the current article, we want to investigate whether a simulation process could induce a potentiation effect in a specific context. Thus, we embedded words into sentences. It is likely that when linguistic stimuli a represented in a sentence context, the simulation could be automatic again. Several works support such a possibility. For instance, [18] used fMRI to determine whether sentences describing actions performed with different effectors (i.e., hand, mouth, or leg) would activate the part of the a granular frontal cortex (i.e., motor, and premotor zones) also activated when participants observe same actions performed by others or when participants perform themselves the same actions. Participants had to simply read sentences or watch videos depicting actions performed with the hand, mouth, or leg. In their experiment, there are two types of sentences, half are literal sentences (e.g., bite the peach) and the other half are metaphorical sentences (e.g., bite more than you can chew). In the left hemispherepremotor cortex, clear cortical congruence was found between the perception of real action by videos and there adding of actions described by literal sentences. In other words, the authors found acongruence between the cortical activation of the actions that were observed and those of the actions that were verbally described. This provides evidence for the involvement of premotor and motor are as in the conceptual process of linguistic sentences that describe actions. This data suggests that come motor activations occurs when participants reading sentences in line with the simulation account.

In another study [19], used Transcranial Magnetic Stimulation (TMS) to test whether listening motor-related linguistic stimulimodulates the activity of the motor system. The TMS was applied in the lef the misphere, more specifically in to the motor area. Dedicating to the control of the hand or foot. This study includes two experiments. In the first, the participants simply had to listen either sentences involving actions with the hand or with the foot or abstract sentences (i.e., control condition). Motor evoked potentials were recorded from hand and foot muscles. The results showed a modulation of the motor system specific to the effect or describe in the sentences. This result is rather interesting because it shows a specific modulation of the motor system because of the sentences, while the participants did not have explicitly to perform a conceptual task. In the second experiment that was conducted, participants were asked to respond with either hand or foot while listening to the same sentences. Consistent with the results of their first experiment, response times were slower when the participants responded with the same effector as the one involved in the sentences. These interference effect would be due to the simultaneous involvement of the motor system into language processing as well as the achievement of the motor task. It is note worthy that [20] tried to replicate the study by [19]. Their main purpose was to enlarge the sample size and replicate the results with higher statistical power.

The TMS experiment showed significant modulation of hand MEP. They found a motor facilitation when processing hand-related verbs. The direction of the effect is accordingly reversed compared to [19] who instead showed an interference effect. In addition, they failed to find any effect in the behavioral experiment. All this behavioral and psychophysiological evidence suggests that a process of simulation might be at work when words appeared into a sentence or when presented with an action verb (even whether some results seem less reliable than others).

Our current study

Accordingly, our goal is twofold. First, we want to test the automatic nature of the simulation process when processing words embedded in a sentence which contains an action verb. Therefore, we used a color categorization task. It is possible that in [16], we failed to find any evidence of the involvement of a simulation process because words we represented in isolation (i.e., not embedded into a sentence or associated with an action verb). Thus, we compared two conditions, one in which each name of the grasp able objects was preceded by an action verb (e.g., GRASP) and one in which they are preceded by a non-word (i.e., condition control). Otherwise, we also want to test the size-coding hypothesis on pictures of graspable objects (e.g., Apple; Strawberry) presented in real size. According to the size coding account even when we presented an action verb just before displaying a picture representing a graspable object, this will not disturb the motor potentiation effect to occur.

Thus, we conducted two experiments. In the first experiment, each trial started with a fixation cross, immediately followed by an action verb (i.e., TO GRASP), verb (TOSEE) or a non-word as control condition (i.e., EXLER), itself followed by a determinant (i.e., A or AN).

Then, the name (i.e., words that represent graspable objects) of a fruit or a vegetable was presented (written in black) for 200 or 400 ms. After such a delay, the name turned orange or blue. The colored name was kept on the screen until the participant responded. They were

Instructed to use are sponse device close to the one originally used by Ellis and Tucker (2000) and must perform either a precision grip or a power grip according to the color of the words. Experiment 2 followed the same procedure except for the fact that words denoting graspable objects were replaced by pictures depicting the same objects in a visual size close to their actual size in everyday life. In addition, it is noteworthy that we used two SOA (i.e., 200 or 400 ms) in order to investigate the temporal window of the potentiation effect. Indeed, various works suggest that the use of a simulation process is a transient phenomenon occurring mainly between 0 and 400 ms when words are processed in isolation and when the task does not directly require to process the stimuli at a conceptual level [21].

In both cases, the simulation account and the size coding account of the potentiation effect make different predictions. First, from an embodied viewpoint, we can predict, a potentiation effect both for words (**Experiment 1**) and pictures (**Experiment 2**). More precisely, it is possible to predict that this potentiation effect would be moderated by the action verbs. Two predictions can be made. First, it is possible to predict that a potentiation effect should occur for words/pictures when they were preceded by the verb “TO GRASP” evoking a grasping action rather than the verb “TO SEE”, or the control non-word “EXLER”, because both did not evoke any manual action. It is also conceivable to predict that the potentiation effect occurs for words/pictures when they were preceded by the verb “TO GRASP” and “TO SEE” but not with the control non-word “EXLER”. This last prediction is possible because some authors [22,7] argue that the mere seeing of objects is enough to induce a sensorimotor simulation process. In a nutshell, the simulation account predicts a potentiation effect in both experiments possibly moderated by the kind of verbs. Second, for the size coding account, a potentiation effect is predicted when pictures were used (Experiment 2) but not when words were used (Experiment 1). Indeed, a size coding process of stimuli should happen solely for pictures because their visual size is available while it was not the case for words. In addition to the fact, the size coding account did not predict any moderation of the potentiation effect because of the verbs added. Indeed, such verbs should not influence the size coding process of stimuli. Accordingly, the size coding account solely predicts a potentiation effect in Experiment 2 and no moderation by the kind of verbs.

Experiment 1

Method

Participants: The sample of our first experiment was composed of 26 participants. They were all students at the University Paris-Nanterre. Our sample included 6 females and 24 right- handed. The average age was 20.23 years (sage = 1.42). They all reported having normal or corrected-to-normal visual acuity and no color perception issues (e.g., color blind). French is the mother tongue of all participants. All participants were naïve to the goal of the experiment. They all reported correctly perceiving the names and pictures of objects presented during the experiment. This study was conducted in accordance with the ethical principles of the American Psychological Association (2016).

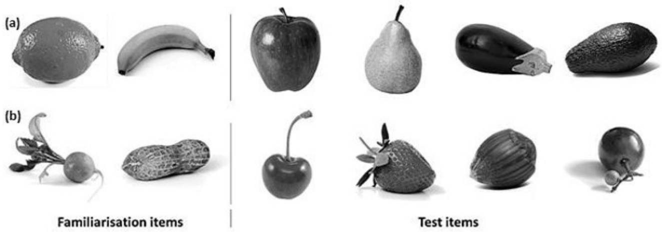
Materials and apparatus

First, we used twelve words denoting objects belonging to the category of fruits and vegetables. Six names denoted large fruits or vegetables usually grasped with a power grip (i.e., apple, avocado, banana, eggplant, lemon, and pear), and six names denoted small fruits or vegetables usually grasped with a precision grip (i.e., cherry, grape, hazelnut, peanut, radish, and strawberry). Eight names were used during the test phase while the four remaining names were used during familiarization trials (see Appendix A). Since our task was to discriminate the color of these names, we carried out three versions of each name: A black, a blue, and an orange version. They were all written on a white background, and they all appeared in a visual size of 72 font. We already used this set of names in our previous work in which we have already checked that the number of letters did not differ between names denoting large and small objects [16]. Our goal was to ensure that there was no visual size difference because of the word length. We also controlled other psycholinguistic variables [16]. All data were reported in Appendix A.

Appendix A: List of words used with (1) the phase in which they were used (familiarization or test), (2) the size associated to the object denoted (large or small), (3) their English names, (4) their French names, (5) their associated film-frequency (from Lexique 3.org, New et al., 2004), (6) their associated book-frequency (also from Lexique3.org, New et al., 2004) and (7) their 839 number of letters. Both frequencies were reported per million of occurrences.

Phase	Associated size	English name	French name	Film frequency	Book Frequency	Number of letters
Familiarization	Large	LEMON	CITRON	8.10	9.05	6
Familiarization	Large	BANANA	BABANE	6,09	4,05	6
Familiarization	Small	RADISH	RADIS	1,81	3,11	5
Familiarization	Small	PEANUT	CACAHUETTE	1,71	0,74	10
Test	Large	APPLE	POMME	19,77	46,08	5
Test	Large	PEAR	POIRE	5,67	10,81	5
Test	Large	EGGPLANT	AUBERGINE	0,35	0,61	9
Test	Large	AVOCADO	AVOCAT	89,28	24,32	6
Test	Small	CHERRY	CERISE	2,75	3,31	6
Test	Small	STRAWBERRY	FRAISE	5,28	3,92	6
Test	Small	HAZELNUT	NOISETTE	0,57	1,69	8
Test	Small	GRAPE	RAISIN	5,88	4,86	6

We also used twelve pictures representing the fruit and vegetable denoted by these names (see Appendix B). All pictures were in grayscale and were presented on a white background and in a visual size corresponding to the actual size of the fruits and vegetables depicted (i.e., large objects ≈ 10 cm and small objects ≈ 3 cm).



Appendix B: List of words used with (1) the phase in which they were used (familiarization or test), (2) the size associated to the object denoted (large or small), (3) their English names, (4) their French names, (5) their associated film-frequency (from Lexique 3.org, New et al., 2004), (6) their associated book-frequency (also from Lexique3.org, New et al., 2004) and (7) their 839 number of letters. Both frequencies were reported per million of occurrences.

We also used two verbs. One is an action verb describing a grasping action: "SAISIR" in French (TO GRASP in English). The other is "VOIR" in French (TO SEE in English). As a control condition, we also used a non-word: "EXLER". It was created thanks to "Word Gen", a non-word generator (Duyck et al., 2004). We choose a five-letters pseudo-word.

The response device was composed of two components that could be taken in one hand at the same time. The first was a small cube (1 cm^3) held with a precision grip between the thumb and index-digit. The cube contained a very small switch that required simultaneous pressure of the two digits to be activated. The second component was a larger PVC cylinder (10 cm tall and 3 cm in diameter) that was held with a power grip. A switch was placed on the free side of the cylinder that was activated when participants squeezed the cylinder with their middle, ring, and little digits simultaneously. We already used the same device in [16]. It is Both responses were recorded using E-prime v2.0 software on an HP probook 650 G1. I3-4000M, 2.4 GHz computer.

Procedure

The experiment was run in a quiet room, participant was seated facing the monitor (23"; refresh rate: 60 Hz), positioned approximately 60 cm from the participant. In the first phase of the experiment, the twelve names denoting each fruit and vegetable were presented successively written under a grayscale version of the fruit or vegetable that they denoted. Participants simply read aloud the name of each item. The duration of the name's presentation was controlled by the experimenter, and their order was randomized. In the second phase, the same procedure was repeated except that the pictures were presented without the name of the fruit or vegetable. The aim of these two first preliminary phases was to be sure that the participant correctly knew each fruit and vegetable used in the experimental phases [23].

This preliminary phase was followed by two critical phases, a familiarization phase, and a test phase, both using a similar procedure. During each trial, participants first saw a fixation cross presented in the center of the screen for 500 ms. Then, a word was presented. It was either "SAISIR" (i.e., TO GRASP), "VOIR" (i.e., TO SEE), or EXLER during 400 ms. It was presented in the center of the screen written in black on a white background. This word was followed by a determinant (i.e., "a" or "an"; according to the name that followed, we used "un" or "une" in French) during also 400 ms that was itself presented in the center of the screen written in black on a white background. Right after, the name of a fruit or of a vegetable was presented in the center of the screen, also written in black on a white background, for 200 or 400 ms. Finally, this name was colored in orange or blue and it remained on the screen until the participant responded. Following the response, a blank screen appeared for 1500 ms before the next trial commenced.

Participants were instructed to categorize, as soon as possible, the colors of the words. An explanation was provided about the mapping between each switch response and each color (i.e.,power grip for blue vs. precision grip for orange; counterbalanced between participants). It is noteworthy that to prevent habituation to items, the fruit/vegetable used in the familiarization phase (i.e., peanut, radish, banana, and lemon), were different to the ones used in the test phase (i.e., cherry, grape, hazelnut, strawberry, apple, avocado eggplant, and pear). In addition, to prevent responses' anticipation, names written in black were presented either during 200 or 400 ms. Accordingly, each word (i.e., TO GRASP, TO SEE, and EXLER) were presented with each name (e.g., TO GRASP/AN/APPLE or TO SEE/A/STRAWBERRY). Thus, there are 24 possibilities in the test phase and 12 possibilities in the familiarization phase.

The test phase was composed of 2 blocks of 96 trials (192 trials). In each bloc, we randomly presented four times each eight test names with each three words (24 possibilities). In a half of trials, names were colored in orange and for the other half, they were colored in blue. Similarly, in half of the trials, names were presented during 200 ms while for the other half, they were presented during 400 ms. The familiarization phase was composed of 12 trials. In the final phase of the experiment, participants completed a short questionnaire and the Edinburgh Handedness Inventory [24].

Results

We solely examined Response Times (RTs) because there were too few errors (2.52%). Accordingly, we used a repeated measures ANOVA with the participants as a random factor, the type of verbs (EXLER vs. TO GRASP vs. TO SEE), the conceptual size of the word (large vs. small), and the type of responses (power grip vs. precision grip) as within factors. We removed RTs from familiarization trials, from incorrect test trials (2.52% of the data), and below 200 ms or above 1200 ms (1,28% of the data) following the methodology used in our previous study [16].

First, the ANOVA did not reveal any statistically significant main effects: (1) the type p of responses, $F(1, 25) = 0.56$, $p = 0.45$, $\eta 2 = 0.02$ (mprecision grip response= 479 ms, sprecision grip response= 71 vs. mpower grip response= 484 ms, spower grip response= 67), (2) the conceptual size of the word, F(1, p 25) = 1.76, $p = 0.19$, $\eta 2 = 0.06$ (mconceptual size [Large] of the word = 484ms, s conceptual size [Large] of the word 365 = 73 vs. m conceptual size [Small] of the word = 479 ms, s conceptual size [Small] of the word = 65) and (3) the type p 366 of verbs, $F(1, 25) = 0.13$, $p = 0.87$, $\eta 2 = 0.00$ (mgrasp = 482 ms, sgrasp= 67 vs. msee = 482 ms, ssee= 72 vs. mexler= 480 ms, sexler= 69). Moreover, the ANOVA did not reveal a statistically significant p Conceptual Size of x Verbs Type interaction, F(1, 25)

= 1,87, p = 0.16, η2= 0.06, nor Verbs p type x Response Type interaction, F(1, 25) = 1.33, p = 0.27, η2= 0.05. More importantly, the ANOVA did not reveal a statistically significant Conceptual Size x Response Type interaction, p F(1, 25) = 1.88, p = 0.18, η2= 0.07. According to the corrected significance threshold (corrected test-wise α = .025 after a Bonferroni correction considering a family of two comparisons). The planned comparisons did not reveal a statistical difference between a power grip RTs for words with a large conceptual size (m = 485 ms, s = 70) and words with a small conceptual size (m = p 483 ms, s = 66), F(1, 25) =0.06, p = 0.79, η2= 0.00, alike the difference between precision grip RTs for words with a small conceptual size (m = 474 ms, s = 65) and words with a large p conceptual size (m = 483 ms, s = 76), F(1, 25) =3.38, p = 0.07, η2=0.12.

Interestingly, the ANOVA did not reveal a statistically significant of the three-way interaction (Verbs type x Conceptual Size x Responses Type interaction) (see Figure 1), F(1,p 25) = 0.91, p = 0.40, η2= 0.03. Nevertheless, if we closely look at Figure 1, we can see a slightly different pattern between verbs and non-words. Thus, to go further, we achieved planned comparisons. According to the corrected significance threshold (corrected test-wise α = .008 after a Bonferroni correction considering a family of six comparisons). First, for the verb TO SEE, the planned comparisons did not reveal a statistical difference between power grip RTs for words with a large conceptual size (m = 488 ms, s = 80) and words with a small conceptual p size (m = 485 ms, s = 71), F(1, 25) =0.19, p = 0.66, η2= 0.0, while the difference between precision grip RTs for word with a small conceptual size (m = 467 ms, s = 58) and words with a large conceptual size (m = 490 ms, s = 79) was statistically significant, F(1, 25) =6.63, p = p0.01, η2=0.21. Second, for the verb TO GRASP, the planned comparisons did not reveal a statistical difference between power grip RTs for words with a large conceptual size (m = 491 ms, s = 65) and words with a small conceptual size (m = 484 ms, s =59), F(1, 25) = 0.71, p =p 0.40, η2= 0.03, like the difference between precision grip RTs for words with a small conceptual size (m = 472 ms, s = 68) and words with a large conceptual size (m = 480 ms, s = 77), F(1, 25) p= 0.90, p = 0.34, η2= 0.04. Third, for the non-word EXLER, the planned comparisons did not reveal a statistical difference between power grip RTs for words with a large conceptual size (m = 476 ms, s = 66) and for words with a small conceptual size (m = 482 ms, s = 69), F(1, 25) p= 0.31, p = 0.58, η2= 0.01, as well as the difference between precision grip RTs words with a large conceptual size (m = 479 ms, s = 76), and for words with a small conceptual size (m = p ms, s = 71), F(1, 25) = 0.23, p = 0.63, η2= 0.01.

Discussion

Our main objective was to test if action verb were able to induce a sensorimotor simulation with words of graspable objects. For this, we performed a color categorization task on names of objects embedded in a sentence containing an action verb. Therefore, we seek to show whether the potentiation effect of words can be moderated by action verbs. The results show absence of motor potentiation effect. More importantly, the Verbs (TO GRASP, TO SEE) and the non- word (EXLER) not modulate the potentiation effect. First, these results are consistent with the study of [16] in which the mere perception of a word representing a graspable object was not sufficient to generate a potentiation effect in the peculiar case of a color categorization task while it is not consistent with the simulationnist account [1,3]. Indeed, according to this last view, the mere vision of words should induce a sensorimotor simulation able to induce a potentiation effect. Even more so, when the words were preceded by an action verb like "GRASP" or the verb "SEE" which can promote the activation of micro-affordances. Thus, our results instead suggest that a sensorimotor simulation does not seem to be at work when graspable object words are automatically processed.

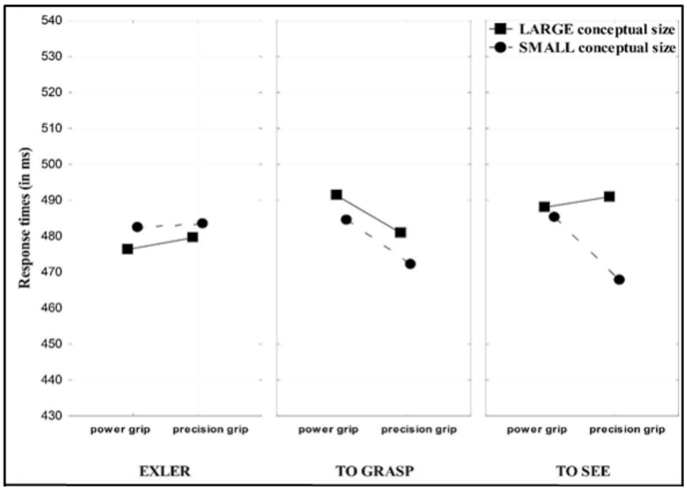


Figure 1: Mean RTs (in ms) of Experiment 1 according to the type of verbs (EXLER *vs*. TOGRASP *vs*. TO SEE), the conceptual size of the word (large vs. small), and the type of responses (power-grip vs. precision grip).

On the other hand, this lack of a potentiation effect is consistent with the size coding account. Indeed, according to this view, size coding only occurs when visual size is available through the pictures, whereas in this experiment only words were presented. Furthermore, as predicted by the size coding account, no moderation of the potentiation effect with the action verbs was observed. Taken together, these results of the first experiment reinforce the size coding account as part of a color categorization task that requires automatic processing rather than a motor simulation as suggested by simulationnist account.

To go further, we carried out a second experiment which has almost the same procedure as the first one except that words have been replaced by pictures depicting the same objects. It is noteworthy that graspable objects were depicted in a visual size matching their actual one. Thus, pictures that represent large objects (e.g., apple, pear) are visually larger than pictures that represent small objects (e.g., cherry, strawberry). Our main goal was twofold. First, we want to investigate whether a potentiation effect can be obtained when the visual size is available. Second, we want to test whether such a visual-based potentiation effect could be modulated by the kind of verb preceding the picture. According to the simulationnist account, we can expect a modulation of the potentiation effect while the size coding account, not predict any influence of verbs.

Experiment 2

Method

Participants

The sample of our second experiment was composed of 27 participants. They were all students at the University Paris-Nanterre. Our sample included 8 females and 26 right- handed. The average age was 19.85 years (sage = 0.98). They all reported having normal or corrected-to-normal visual acuity and no color perception issues (e.g., color blind). French is the mother tongue of all participants. All participants were naïve to the goal of the experiment. They all reported correctly perceiving the names and pictures of objects presented during the experiment. This study was conducted in accordance with the ethical principles of the [31].

Material and apparatus and procedure

This experiment was similar to Experiment 1 except that we used pictures of objects instead of their name. Accordingly, the twelve names used in Experiment 1 were replaced by twelve pictures depicting the same fruits/vegetables [15,16]. Six pictures were large fruits or vegetables usually grasped with a power grip (i.e., apple, avocado, banana, eggplant, lemon, and pear) and six were small fruits or vegetables usually grasped with a precision grip (i.e., cherry, grape, hazelnut, peanut, radish, and strawberry). We used 8 pictures during the test phase while the 4 remaining pictures were used during the familiarization phase (see Appendix B). We designed three versions of each picture: a grayscale, a blue, and an orange version. All pictures were presented on a white background and in a visual size corresponding to the actual size of the fruits and vegetables depicted (i.e., large objects ≈ 10 cm and small objects ≈ 3 cm).

The procedure was also like that of Experiment 1 with the exception to that fact that during each trial, the names of objects were replaced by pictures. Thus, each trial proceeded as follows: First, participants saw the fixation cross (500 ms) followed by one of the three possible words (i.e., TO GRASP, TO SEE, or EXLER) during 400 ms, itself followed by a determinant also during 400 ms. Immediately after the grayscale version of the picture of a fruit or of a vegetable was presented in the center of the screen. After 200 or 400 ms, the picture was colored in orange or blue. After participants responded, a blank screen appeared for 1500 ms before the next trial commenced.

Results

We solely examined Response Times (RTs) because there were too few errors (2,32%). Accordingly, we used a repeated measures ANOVA with the participants as a random factor, the type of verbs (EXLER vs. TO GRASP vs. TO SEE), the visual size of pictures (large vs.small) and the type of responses (power grip vs. precision grip) as within factors. We removed RTs from familiarization trials, from incorrect test trials (2,32% of the data), and below 200 ms or above 1200 ms (1,19% of the data).

As in the first experiment, the ANOVA did not reveal neither a main effect of the Verbs Type, p F(1, 26) = 1.01, p = 0.37, η2 = 0.03 (mgrasp = 477 ms, sgrasp= 72 vs. msee = 472 ms, ssee= 68 vs.mexler= 470 ms, sexler= 63) , nor a main effect of the type of responses, F(1, 26) = 0.76, p = 0.38, p η2 = 0.02 (mprecision grip response= 470 ms, sprecision grip response= 69 vs. mpower grip response= 476 ms, spower grip response= 66). On the other hand, unlike the first experiment, the ANOVA revealed a main p effect of the visual size of picture, F(1, 26) = 6.88, p = 0.01, η2 = 0.20. Participants' RTs was shorter when responding to large objects (m = 469 ms, s = 69) than to small ones (m = 477 ms, 488 s = 67).

Moreover, the ANOVA did not reveal a statistically significant Visual Size x Verbs p Type interaction, F(1, 26) = 0.89, p = 0.41, η2= 0.03, nor a statistically significant Verbs type p x Response Type interaction, F(1, 26) = 1.80, p = 0.17, η2= 0.06. More importantly and unlike Experiment 1, the ANOVA revealed a statistically significant Visual Size x Response Type p interaction, F(1, 26) = 18.3, p = 0.0002, η2= 0.41.

According to the corrected significance threshold (corrected test-wise α = .025 after a Bonferroni correction considering a family of two comparisons), planned comparisons revealed that the difference between power grip RTs for large objects (m = 459 ms, s = 62) and for small ones (m = 493 ms, s = 65) was statistically p significant, F(1, 26) =26.94, p = 0.00002, η2= 0.51, alike the difference between precision grip RTs for small objects (m = 460 ms, s = 64) compared to large one (m = 479 ms, s = 73), F(1,p 26) = 6.60, p = 0.01, η2= 0.20.

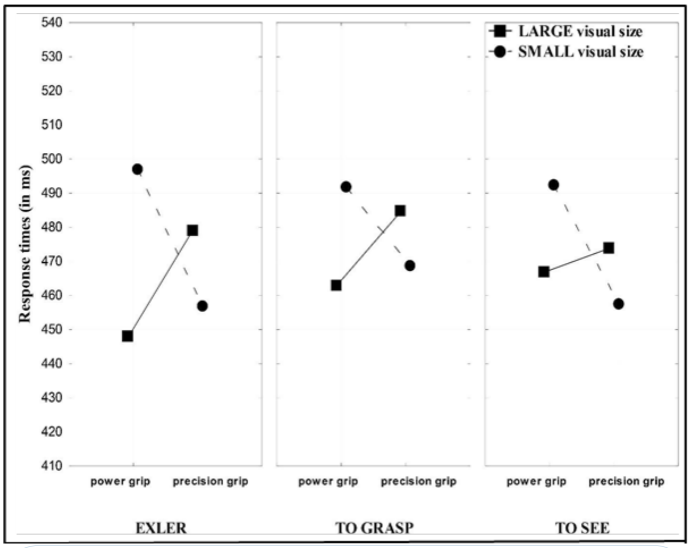


Figure 2: Mean RTs (in ms) of Experiment 2 according to the type of verbs (EXLER *vs*. TOGRAB *vs*. TO SEE), to the visual size of the picture (large vs. small), and the type of responses (powergrip *vs*. precision grip).

Discussion

In this second experiment, our goal is to test whether the potentiation effect with pictures could be moderated by action verbs. Even in our last study [16] we have already succeeded in having a potentiation effect with the same picture used in this study, the fact of integrating action verbs into our procedure seems to slightly disrupt the potentiation effect for pictures. More precisely, unlike our first experiment, the potentiation effect is significant. Indeed power grip RTs were faster when large than small objects were presented while precision grip RTs were faster when small than large objects were presented. Obviously, when the visual size of the object is available thanks to the picture, the potentiation effect occurs as predicted by the size coding account. Second and most importantly, the type of verb used modulate the potentiation effect. We observed a significant potentiation effect for the power grip with the two verbs (TO GRASP and TO SEE) and the non-word (EXLER), while we observed a significant potentiation effect for the precision grip only for (EXLER). However, what we found to be even more surprising was that the most important interaction occurs with the non-word "EXLER". This last result can be explained as follow. From a simulationnist account, one should expect a reverse effect: a facilitation when the verb GRASP precedes the picture, or eventually the verb SEE. Thomas (2015), on the other hand, reported data suggesting that precision grip (compared with power grip) could be more linked to the parvocellular pathway that possibly suggest a closer link to the ventral stream. This ventral pathway involved in object recognition and thus essentially involves knowledge. Thereby, it could be argued that since the verbs, ''TO SEE'' and ''TO GRASP'' can activate micro affordances activating the motor system whereas the precision grip response is more related to knowledge, this can disrupt the coding process for pictures with this specific response. This could explain the fact that we observe a potentiation effect for the precision grip with the non-word ''EXLER'' unlike ''TO SEE'' and ''TO GRASP'', because this non-word used as a control condition has not activated the motor system and therefore does not disturb the size coding of pictures. In any case, this modulation of verbs for the potentiation effect should not be taken lightly. Even if for the moment we cannot say anything with certainty, this path deserves to be further explored in order to help us better understand the potentiation effect of grasping behaviours for linguistic stimuli.

General discussion

Our main goal was to better understand the potentiation effect of grasping behaviours [22,7,13] with linguistic stimuli. Indeed, some researchers suggest that the potentiation effect stems from a motor simulation [3,22,7,13]. Others, however, assume instead that the involvement of size code process [15,16,17,25]. Overall, our results mainly support the size coding account. Nevertheless, some results are consistent with the simulationnist account. We further discuss our results in the three following sub-sections.

The simulationnist account

In our first experiment, we did not obtain any potentiation effect on words. This result is not consistent with the simulationnist account which predicts an effect on words even when the task does not involve conceptual processing. According to this point of view, the simple perception of a graspable object or its name is sufficient to induce a motor simulation which produces a motor potentiation effect. It is noteworthy that, initially, proponents of the simulationnist account argue that the motor simulation should take place automatically [1]. However, if stimuli have necessarily to be process at a conceptual level, it would mean that the motor simulation process is not as automatic as originally envisioned and would not be a universal process but rather something that requires some intentionality. In fact [13], successfully generated a potentiation effect with words using a semantic categorization task that can promote the conceptual processing of the words while we rather used a colour categorization task, which did not require such a level of processing. Therefore, it is possible that the automatic processing of the words in this first experiment prevent the occurrence of a motor simulation and in turn, the occurrence of any potentiation effect. This interpretation is in line with the view of [21] who argue that task used is a critical factor into the emergence potentiation effect in the case of linguistic stimuli. Indeed, they explained that, in their review, the potentiation effect occurs more systematically in the case of a semantic categorization task while it is not the case when the task require a color categorization of the words. Nevertheless, in our previous study [16], we generated a potentiation effect with words, when they presented with pictures even with a task that does not require conceptual processing. However, several studies suggest that action verbs can modulate the motor system (e.g., Boulenger et al., 2008; Fargier et al., 2012; Hauk et al., 2005; Moreno et al. 2013; Willems et al., 2010). Furthermore, some studies have succeeded in obtaining a potentiation effect when linguistic stimuli were presented in the context of a sentence with a task that does not require a conceptual process [18,19] suggesting that a motor simulation process can take place automatically with linguistic stimuli presented in a sentence that contains an action verb. Based on this idea, in our current work we added an action verb preceding before the target stimuli in order to create a linguistic context able to increase the possible to use a motor simulation process.

Whereas in the second experiment and, when pictures representing natural objects were used, a potentiation effect was obtained even with a task that requires automatic processing. (i.e., color categorization task). In addition, this potentiation effect is moderated by the action verbs but not as the simulationnist account predicted [1,3]. Indeed, even if a potentiation effect was obtained with the verb "TO GRASP" and the verb "TO SEE", the partial square state indicates to us that the greatest interaction was obtained with the non-word "EXLER". Now if we look precisely at what is happening, the comparison plan tells us that things are not going the same way for precision grip and power grip responses. In point of fact for the "Power grip" the interaction is confirmed for the two action verbs, "TO GRASP" and "TO SEE" and for the non-word "EXLER". While for precision grip the interaction is not confirmed for "TO GRASP" and "TO SEE" unlike "EXLER". This different influence of "Power grip" and "Precision grip" is also present in the literature. Some researchers suggest that the precision grip which is a finer grip that might be more knowledge sensitive. For instance [27], reported data suggesting that precision grip (compared with power grip) could be more linked to the parvocellular pathway that possibly suggest a closer link to the ventral stream. This ventral pathway extends from the primary visual cortex to the intertemporal lobe and is involved in object recognition.

Thus normally, with the verb "TO GRASP" one could expect an important effect of precision grip being that the verb evokes a manual action, and that precision grip is sensitive to knowledge. Instead, we observed an inhibition of this interaction with the precision grip for the verb "TO GRASP" and "TO SEE", unlike the non-word EXLER. One could argue that given that the precision grip is primarily linked to the ventral pathway which involves an influence of knowledge, it is possible that following the perception of the verbs ''TO GRASP'' and ''TO SEE'' (who could activate micro-affordance) there is an activation of the motor system by mobilizing the precision grip and thus disrupts the process of coding the visual size of picture specifically for this response. Nevertheless, this mobilization of precision grip with the verbs ''TO SEE'' and ''TO GRASP'' could be partial, which could explain why no influence of these verbs was observed during our first experiment. This could also explain the fact that, we observed a potentiation effect for the precision grip with the non-word ''EXLER'' unlike ''TO SEE'' and ''TO GRASP''. That is due to the fact that, this non-word used as a control condition has not activated the motor system and therefore does not disturb the coding of pictures. Thus, it is conceivable that the language can activate the motor system in a more important way when the task involves conceptual processing while it activates it in a partial way if the task requires automatic processing. Therefore, our results suggest that there could be a simulation process that takes place in parallel with the coding. Nevertheless, it is necessary to use other types of tasks to confirm these suggestions in a stronger way. More specifically, it would be wise to establish a protocol with linguistic stimuli in which two experiments are established with a variation of the nature of the task for each of them. The first, for example, will use a task that would involve automatic processing while the second would involve conceptual processing. Indeed, this will allow us to observe the difference between these two tasks for the modulation of the motor system with linguistic stimuli.

Size coding account

In agreement with the predictions of a size coding account, we did not obtain a potentiation effect in our first experiment with words which could be explained by the fact that the visual size of the words was controlled nor allows their size coding. Additionally, verbs did not modulate the potentiation effect for words in line with the size coding account. On the other hand, in our second experiment when pictures were presented in a visual size that corresponds to their actual size a motor potentiation effect was obtained, according to the prediction of the size coding account. Obviously, this potentiation effect obtained during our second experiment is due to the availability of the visual size of the picture that represent objects. Because, unlike our second experiment, when visual object size was not available the size coding of words is not occurred. Presumably, in a color task that involves automatic processing, the size coding account better explain the emergence of a potentiation effect without resorting to a simulation process (for converging evidence) [16]. Our results are consistent with some studies in the literature [25,27] which show that it is possible to generate stimulus-response compatibility effects with color categorization tasks. In addition [25], study provides major support for the size coding account compared to the simulation account given that no compatibility effect was provided when the task was a judgment on the form or even the orientation, which is assumed to be more appropriate for causing a simulation than a color categorization task. However, things are not that simple, several studies in the literature on the stimuli-response compatibility effect suggest that the color categorization task does not achieve a motor potentiation effect. Indeed [28], suggest that a color categorization task did not elicit a compatibility effect, unlike orientation judgments. [29] find a compatibility effect when judgments of orientation, form, or even function are used, unlike a color categorization task. Another study by [30] reports converging evidence suggesting that a compatibility effect occurs when participants made judgments about the shape but not color. Overall, the results of our experiments demonstrate the critical role of visual size [16] of objects and suggest that the size coding account is the best suited to explain this potentiation effect as part of a color task that requires automatic processing.

A limitation of the size coding account

Even if the potentiation effect in our second experiment can explained by the size coding account, the fact that verbs modulate the potentiation effect is difficult to explain using thisapproach. Indeed, according to this view, there should not be a modulation of action verbs or other kind of verb for the motor potentiation effect occurrence. So, the fact that there is this moderation of verbs tells us that it is possible in some cases, the coding is implemented in parallel with other secondary processes (e.g., simulation). However, other supplementary results will be necessary to confirm this, especially with using a semantic categorization task rather a color categorization task as we have done.

Conclusion

Our experiments reveal a critical role of the visual size in which the objects were presented. The results of the experiments suggest that the potentiation effect can be explained by a size coding account rather than by motor simulation as part of a color categorization task that requires automatic processing. However, our results also suggest that there could be simulation process that takes place in parallel with the size coding. In order better understand the stimulus- response compatibility effect of grasping behaviors with linguistic stimuli, future studies should focus on the use of two tasks with different nature for the same protocol. For example, implemented a task that involves automatic processing for the first experiment and implemented a task that involves conceptual processing for the second experiment. This will allow observation the specific modulation of task for motor system with linguistic stimuli.

Declarations

Conflict of interest: All authors declare that they have no conflict of interest.

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Ethical approval: All procedures performed in studies involving human participants were in 699 accordance with the ethical standards of the institutional research committee and with the 1964 700 Helsinki declaration and its later amendments or comparable ethical standards.

Informed consent: Informed consent was obtained from all individual participants included in the study.

Availability of data and materials: https://osf.io/v3r6w

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