A peer-reviewed version of this preprint was published in PeerJ on 7 December 2018.

View the peer-reviewed version (peerj.com/articles/5987), which is the preferred citable publication unless you specifically need to cite this preprint.

Mazzuca C, Lugli L, Benassi M, Nicoletti R, Borghi AM. 2018. Abstract, emotional and concrete concepts and the activation of mouth-hand effectors. PeerJ 6:e5987 https://doi.org/10.7717/peerj.5987

PeerJ Preprints NOT PEER-REVIEWED

Abstract, emotional and concrete concepts and the activation of mouth-hand effectors.

According to embodied and grounded theories concepts are grounded in sensorimotor systems. The majority of evidence supporting these views concerns concepts referring to objects or actions, while evidence on abstract concepts is more scarce. Explaining how abstract concepts, as “freedom”, are represented, would however be pivotal for grounded theories. According to some recent proposals, abstract concepts are grounded evoking both sensorimotor and linguistic experience, thus activating the mouth motor system more than concrete concepts. Two experiments are reported, aimed at verifying whether abstract, concrete and emotional words activate the mouth and hand effectors. In both experiments participants performed first a lexical decision, then a recognition task. In Experiment 1 participants responded by pressing a button either with the mouth or with the hand, in Experiment 2 responses were given with the foot, while a button held either in the mouth or in the hand was used to respond to catch-trials. Abstract words were slower to process in both tasks (concreteness effect). Across the tasks and experiments, emotional concepts had instead a fluctuating pattern, different from those of both concrete and abstract concepts, suggesting that they cannot be considered as a subset of abstract concepts. The interaction between kind of concept (abstract, concrete and emotional) and effector (mouth, hand) was not significant in the lexical decision task, likely because it emerged only with tasks implying a deeper processing level. It reached significance, instead, in the accuracy analyses of the recognition tasks. In both experiments abstract concepts yielded less errors in the mouth than in the hand condition, supporting our main prediction. Emotional concepts had instead a more variable pattern. Overall, our findings indicate that different kinds of concepts differently activate the mouth and hand effectors, but they also suggests that concepts activate effectors in a flexible and task-dependent way.

PeerJ Preprints | https://doi.org/10.7287/peerj.preprints.26559v2 | CC BY 4.0 Open Access | rec: 6 Mar 2018, publ: 6 Mar 2018

PeerJ Preprints NOT PEER-REVIEWED

Abstract, Emotional and Concrete Concepts and the activation of mouth-hand effectors.

Claudia Mazzuca[1], Luisa Lugli[2], Roberto Nicoletti[3], Anna M. Borghi[4,5]
[1] Department of Philosophy and Communication, University of Bologna, Italy
[2] Department of Philosophy and Communication, University of Bologna, Italy
[3] Department of Philosophy and Communication, University of Bologna, Italy
[4] Department of Dynamic and Clinical Psychology, Sapienza University of Rome, Italy
[5] Institute of Cognitive Sciences and Technologies, Italian National Research Council, Rome, Italy

Corresponding Author:
Anna M. Borghi[4,5]
Via dei Marsi 78, Rome, 00185, Italy
Via San Martino della Battaglia 44, Rome, 00185, Italy
anna.borghi@gmail.com
Claudia Mazzuca[1]
Via Azzo Gardino 23, Bologna, 40122, Italy
Email address: mazzuca.claudia@gmail.com, claudia.mazzuca2@unibo.it

PeerJ Preprints | https://doi.org/10.7287/peerj.preprints.26559v2 | CC BY 4.0 Open Access | rec: 6 Mar 2018, publ: 6 Mar 2018

Introduction

When we process and recognize words, do we activate the body? Do different kinds of words, as abstract, concrete and emotional words, activate different effectors, as the mouth and the hand? Is this eventual activation modulated by the task?

The last years have seen the widespread of embodied and grounded (from now on grounded) theories of cognition (Barsalou, 2008, 2010, 2016; Glenberg, 2015; Glenberg et al., 2013; Borghi & Caruana, 2015), according to which concepts and words activate our bodily interactions with the world. A lot of compelling evidence has demonstrated that when we hear words as for example 'ball' we re-enact previous interactions with the word referent, activating the sensorimotor system. This is particularly true for words that refer to object or actions (Cappa & Pulvermueller, 2012; Glenberg & Gallese, 2012).

Explaining how also abstract concepts and words, as "fantasy" and "beauty", are grounded in the sensorimotor system, represents a major challenge for embodied and grounded views, as recent debates testify (for recent reviews, see Borghi et al., 2017; Pecher et al., 2011; Wang et al., 2017; for special topics see Tomasino & Rumiati, 2013, Frontiers in Human Neuroscience; Dove, 2015, Frontiers in Psychology; Mahon & Hickok, 2016, Psychonomic Bulletin & Review; Bolognesi et al., Topics in Cognitive Science, in press; Borghi, Barca, Binkofski & Tummolini, Philosophical Transactions of the Royal Society B, in press).

Compared to concrete words, abstract words typically lack a single object as referent, they refer to more complex events and situations (Barsalou, 2003), they are more detached from the five sensorial modalities, they are represented in a more variable way, and they are generally more grounded in internal states (interoception, proprioception) (Connell et al., 2017, accepted; Borghi et al., accepted) (Borghi & Binkofski, 2014).

Two major novelties characterize recent literature on abstract concepts.

The first novelty is represented by the recognition that abstract concepts are not a monolithic whole, but that there might exist sub-kinds of abstract concepts, that are differently represented. To date some studies are starting to explore the differences between abstract concepts as mathematic ones, emotional ones, mental states ones, social concepts, temporal concepts (e.g. Setti & Caramelli, 2005; Ghio et al., 2003; Roversi et al., 2013; Crutch et al., 2013; Mellem et al., 2016; Villani, Lugli, Liuzza & Borghi, in preparation; Borghi et al., accepted). In this framework, it is debated whether emotions are to be considered as a sub-kind of abstract concepts or whether they differ from both concrete and abstract ones (for discussion see Mazzuca et al., 2017; Barca et al., 2017). Altarriba et al. (1999) and Altarriba and Bauer (2004) demonstrated that emotional concepts differ from concrete and abstract ones in ratings on a variety of psycholinguistics criteria, as concreteness, imageability, and contextual availability, that they elicit different word associations, and that in free recall they are recalled better than concrete and abstract concepts. They have even argued that including emotional concepts among abstract concepts can lead to biased results (Altarriba et al., 1999).

For this reason in the present work we will consider abstract, concrete and emotional concepts, separately in order to verify whether emotional concepts are responded to more similarly to concrete or to abstract concepts. The first aim of the present experiment thus consists in comparing processing of abstract, concrete and emotional concepts in a lexical decision task and in a

subsequent recognition task, in order to verify whether they are differently grounded in the sensorimotor system, differently activating the hand and mouth effectors.

The second novelty in current literature is the emergence of multiple representation views (Borghi & Binkofski, 2014; Cuccio & Gallese, accepted; Dove, 2009, 2011; Dreyer & Pulvermuller, 2017; Kousta et al., 2011; Newcombe et al., 2012; Prinz, 2012; Recchia & Jones, 2012). These views represent an extension of grounded ones; they contend that, in order to fully account for abstract concepts representation, other systems (linguistic, emotional) beyond the perception and action systems are likely activated. Among these views, some proposals highlight the importance of language for abstract concepts representation. According to WAT (Words As social Tools) proposal (Borghi et al., accepted; Borghi & Binkofski, 2014; Borghi et al., 2011; Borghi & Cimatti, 2009; Borghi & Zarcone, 2016), words are tools useful to operate in the physical and social environment. Specifically, abstract words would evoke linguistic and social experience more than other words, because they are more complex, more detached from sensorial modalities, and more variable. Indeed, linguistic labels facilitate us in forming categories composed by heterogeneous exemplars, as those of abstract concepts, and inner speech can help us either to retrieve the linguistically conveyed information we received during word acquisition, to re-explain to ourselves the word meaning or to prepare ourselves to ask to others information on the word meaning. In a similar vein, Dove (2014) has proposed that language is useful to improve our thought and our problem solving abilities (see also Clark, 1998; Lupyan & Clark, 2015; Dove, accepted). Consistently with this perspective, literature on Modality of Acquisition (MoA)(Wauters, 2003) has shown that words acquired through the linguistic rather than the perceptual modality, i.e. pointing to their referent, are more abstract and acquired later (see also Thill & Thomey, 2016).

In a grounded perspective, the activation of language would involve the body, and particularly the mouth motor effector. Studies by Topolinski and collaborators (Topolinski and Strack, 2009; Topolinski et al., 2014) have shown that during word reading we activate a simulation of the phono-articulatory aspects of words; here we hypothesize that this simulation is stronger in the case of abstract words, because for them language is particularly relevant.

The second and more important aim of our study is thus to test the hypothesis that processing different kinds of words differently activate the body, involving the mouth and the hand effectors. More specifically, we predict the mouth motor system is more engaged for abstract than for concrete words, due to the fact that abstract concepts activate more linguistic experience. Consistently, previous evidence with has shown that abstract words are rated as involving the mouth more than concrete words (Granito et al., 2015), and that abstract sentences referring to mental states and to emotions are rated as involving the mouth more than math-related abstract sentences (Ghio et al., 2013). Furthermore, behavioral evidence with response times have demonstrated that responses with the mouth were facilitated with abstract compared to concrete concepts in a definition-word-matching task (Borghi & Zarcone, 2016), and recent fMRI evidence has shown that abstract concepts evoke the mouth motor system (Dreyer et al., 2015; Dreyer & Pulvermuller, 2017).

We intend here to investigate whether the facilitation of mouth responses with abstract concepts is present also in a task implying a rather superficial processing level, as the lexical decision task, and to verify whether it affects recognition. Notably, previous evidence on activation of effectors with

verbs was obtained not only with sentences or verbs evaluation tasks (e.g. Buccino et al., 2005;), but also with lexical decision tasks (e.g. Hauk et al., 2004).

To investigate the involvement of the mouth effector in the processing of abstract words compared to concrete and emotional ones, we performed two different experiments. In Experiment 1 participants responded by pressing a button with the hand or with the mouth, in Experiment 2 they kept a button in the hand or in the mouth to respond to catch-trials, but responses to critical trials were given pressing a pedal with the foot.

Experiment 1

Previous results in which participants were required to decide whether a definition matched with a target words revealed that processing of abstract concepts were facilitated with mouth responses, while processing of concrete ones with manual responses (Borghi & Zarcone, 2016). In Experiment 1 we used the same response modality and the same response devices adopted by Borghi and Zarcone. We intended to verify whether the facilitation of abstract over concrete concepts in responses with the mouth was present also in a task involving a more superficial processing level, i.e. a lexical decision task, and in a subsequent recognition task. As to emotional words, we were interested in investigating whether they were processed similarly to other abstract words or whether they differed from both concrete and abstract words.

Method

Participants

Forty native Italian speakers in a range of age between 20-30 years (22 females and 18 males; mean age: 20,1; standard deviation of age: 2,12) participated voluntarily. Handedness was assessed using an abridged version of the Edinburgh Inventory (Oldfield, 1971). All participants were Italian native speakers, had normal or corrected-to-normal vision, and were naïve as to the purpose of the experiment. All participants gave written informed consent, and the experimental procedures were approved by the CNR- ISTC ethics committee.

Materials

We selected 90 Italian words from the Della Rosa et al. database (Della Rosa et al., 2010), composed by 30 concrete words, 30 abstract and 30 words that according to the experimenters had high emotional valence. The selected words were balanced in Familiarity (mean of FAM: 590; *SD*: 148.09). We considered the dimensions of concreteness and abstractness as distinctive for concrete words (mean of CNC: 648.08; mean of ABS: 178.31) and abstract words (mean of CNC: 209.68; mean of ABS:547.92); the emotional words we chose had the following values of abstractness and concreteness (mean of CNC: 343.09; mean of ABS: 408.09).
To verify the emotional valence of words an on-line pre-test was accomplished; we asked 26 participants (14 females and 12 males) to judge the emotional value of each word on a 7-points Likert scale (1 was rated as non-emotional and 7 as completely emotional). Since in the literature it is debated whether emotional words can be considered a subset of abstract concepts or represent a kind of concepts different from both concrete and abstract concepts (Altarriba et al.,1999; Kousta et al., 2011), the pre-test also aimed to clearly distinguish abstract, concrete and emotional words, avoiding overlaps between abstract and emotional words.

Among the original 90 words we selected 48 words composed by 16 concrete, 16 abstract, and 16 emotional words: the average emotional valence of the selected words was 2.13 for concrete words, 4.54 for emotional words and 3.63 for abstract words. We performed a T Student test for independent samples and we calculated the effect size (Cohen's *d*), in order to verify if concrete, abstract and emotional words differed in Concreteness; all the categories (ABSTRACT, CONCRETE and EMOTIONAL) resulted to differ in Concreteness ($p_s < .001$; abstract and concrete's *d*= 12.82; abstract and emotional's *d*= 2.65; concrete and emotional's *d*= 10.82). The abstract and concrete selected words also differed in Imageability, Age of Acquisition, Contextual Availability, Abstractness, Modality of Acquisition and only slightly in Number of Letters (respectively, Imageability t (30) = -18.4, p <.001, *d*= 6.52; Age of Acquisition t (30) = 7.3, p <.00, *d*= 2.60; Contextual Availability, t (30)=-11.7, p <.001, *d*= 4.15; Abstractness, t (30)= 23.7, p <.001, *d*= 0.92; Modality of Acquisition, t (30)= 10.03, p <.001, *d*= 3.54 ; Number of Letters, t (30)= 3.3, p <.05, *d*= 3.72). They did not differ in Familiarity (t (30)= .1, p =.9, *d*= 0.04). The abstract and emotional selected words resulted to differ in Imageability, Age of Acquisition, Contextual Availability, Abstractness and Modality of Acquisition (respectively, Imageability t (30) = -3.9, p <.001, *d*= 1.39; Age of Acquisition t (30)= 3.1, p =.004, d= 1.11; Contextual Availability, t (30)=-3.7, p <.001, *d*= 1.31 ; Abstractness, t (30)= 4.8, p <.001, *d*= 1.70 ; Modality of Acquisition, t (30)= 3.4, p =.002, *d*= 1.20), while they did not differ in Familiarity and Number of Letters (Familiarity: t (30)=.1, p =.9, *d*= 0.04 ; Number of Letters: t (30)=1.2, p =.2, *d*= 0.42). As regards concrete and emotional selected words, they differed in Imageability, Age of Acquisition, Contextual Availability, Abstractness, Modality of Acquisition and Number of Letters (respectively, Imageability t (30) = 17.7, p <.001, *d*= 6.26; Age of Acquisition t (30)= -4.4, p <.001, *d*= 1.59 ; Contextual Availability, t (30)=7.9, p <.001, *d*= 2.80 ; Abstractness, t (30)= -28.2, p <.001, *d*= 9.97; Modality of Acquisition, t (30)= -6.6, p <.001, *d*= 2.34; Number of Letters, t (30)= -2.3, p =.02, *d*= 0.81), while they did not differ in Familiarity (t (30)= .005, p =.9, *d*= 0.00). Abstract and emotional words differed from concrete ones in Frequency (p_s<.05, abstract and concrete *d*= 3.83, emotional and concrete *d*= 4.78). Means of Frequency and number of letters are presented in *Table 1*. Emotional and abstract words did not differ (p=1, *d*= 0.95); concrete words differed from abstract ones in Number of Syllables (p<.05, *d*= 5.23), while emotional words did not differ neighter from concrete nor from abstract words (p_s>.05, emotional and concrete's *d*= 3.33, abstract and emotional's *d*= 1.89).

We subsequently added 48 pseudowords, created by modifying one letter at the beginning, in the middle or at the end of concrete, abstract and emotional words in the same proportion as the critical words. Then we created 24 words to be used as catch-trials: they were Italian words with a bold letter, at the beginning, in the middle or at the end of the word. Finally we selected other 24 new words, maintaining the proportion between abstract, concrete and emotional words for the recognition task. Words that can directly activate hand or mouth (e.g. tools or food related words) were excluded from the list. Stimuli are shown in *Table 1*.

The experiment consisted of two tasks, a lexical decision task and a recognition task, that were presented in sequence; the lexical decision task always preceded the recognition one. Two separate lists of words were created for the two tasks: for the lexical decision task 24 critical words (8 concrete, 8 abstract, 8 emotional), and 24 pseudo-words. For the recognition task list, 24 critical words (8 concrete, 8 abstract and 8 emotional) and 24 new words were used.

Procedure

Participants were tested individually, and were instructed to respond as quickly and accurately as possible to each trial using a response box connected with a pedal and a button (see *Figure 1* and *Figure 2*). They were given the instructions on the computer screen and were trained at the beginning of every task. In no case further instruction from the experimenter was needed; she only needed to specify how to use the button for the mouth responses, and she made sure that participants used their dominant hand for hand's responses. Only the participant and the experimenter were present in the room; after the training the experimenter sat outside the participant in order to avoid any kind of interference with the experiment. Testing took place on a Pc running EPrime2 Professional software. Participants sat on a comfortable chair in front of a computer screen, at a distance of about 60 cm.
Each trial began with a centred black fixation cross for 500 ms, followed by the presentation of the word. Words remained on the screen for a time of maximum 1.5 second. After 1 second the next trial started (see *Figure 3*).

Lexical Decision task
The task was divided into two experimental blocks, each preceded by a training block of 12 trials (6 words and 6 pseudo-words). Depending on the block, participants kept the button to press in their dominant hand or mouth. The order of the blocks was counterbalanced across participants. A set of 48 words was presented on the computer screen (24 critical words, 24 pseudo-words). Participants were asked to press the button with the hand or with the mouth, depending on the instructions, if they read an Italian word, and to refrain from responding if the word they read was not an Italian one.

Recognition task
The task was divided into two experimental blocks, each preceded by a training block of 6 trials (3 words, 3 new words). Depending on the block, participants were required to keep the button in their dominant hand or in the mouth, between the teeth. A set of 48 words was presented in each block, composed by 24 critical words and 24 new words. The order of the blocks was counterbalanced across participants. Participants were asked to press the button with the hand or with the mouth, depending on the condition, in case they recognized words on the screen as words already presented in the previous task, or to refrain from responding if they were new words.

Results

We performed a 3x2 ANOVA on RTs and Errors, for both tasks, on participants and by items, with factors *Type of Concepts* (ABS; CNC; EMO) x *Effector* (Mouth; Hand). In the ANOVA on the recognition task the factor *Congruency* (Congruent; Incongruent) was added. We considered Congruent the trials of the list in which responses to catch-trials were given with the same effector, either the hand or the mouth, in the two tasks; Incongruent trials were those where the effector employed in the two tasks differed. Since the factor Congruency were not significant neither in Experiment 1 nor in Experiment 2 and because we did not have specific hypotheses on it, we considered it as a simple balancing factor. We will therefore discuss the results of the analyses performed without the factor Congruency. For the participants analyses (indicated by F^1), condition means were obtained by averaging across words, and for the items analyses (indicated by F^2) they were obtained by averaging across participants.

Lexical Decision task

All erroneous trials (2,96%) were removed before the analysis of RTs. In the analysis of response times both the main effect of the factor *Type of Concepts* [F_1 (2,78) = 27.29; MS_e =140794.106; p< .001, n_P^2= .417] ; [F_2 (2,45) = 3.59; MS_e =440462.579; p= .03,; n_P^2= .138], and the main effect of the factor *Effector* were significant [F_1 (1,39) = 31.129; MS_e =261172.157; p< .001, n_P^2= .444]; [F_2 (1,45) = 19.581; MS_e =198796.043; p< .001; n_P^2= .303]. A t-test analysis for paired samples and the Effect size (Cohen's *d*) on participants and a t-test analysis for independent samples on materials revealed that abstract words were responded to slower than both concrete [t_1(39)= 6.375; SE= 6.85; p<.001; *d*= 0.43], [t_2(30)=2.130; SE=27.49; p=.04; *d*=0.7] and emotional words [t_1(39)= 6.239; SE=6.92; p<.001; *d*= 0.42], [t_2(30)= 2.027; SE=27.72; p=.05; *d*=0.7] (see *Table 4*); (means participants: ABS: 715.5; CNC:671.7; EMO: 672.3). (means materials A: 730,9 ms; C: 672,3 ms; E: 674,7 ms). The *Effector* effect was due to the faster response times with the Hand, likely due to the higher difficulty in pressing the device with the mouth (see also Borghi & Zarcone, 2016). The interaction between the factors *Type of Concept* x *Effector* didn't reach significance [p=.82];the means of RTs are shown in *Table 2*.

In the analysis on the accuracy the main effect of the factor *Type of Concept* was significant [F_1 (2,78) = 3.11; MS_e =22.842; p=.05; n_P^2= .074];[F_2 (2,45)=1.34; MS_e = 76. 09; p >.05; n_P^2= .057] (Mean ABS= 0.3; Mean CNC=0.2; Mean EMO= 0.1); means of errors are shown in *Table 3*. A t-test analysis on paired samples and Effect size (Cohen's *d*) revealed that responses to abstract words produced significantly more errors than responses to emotional words [t(39)= 2.379; SE=0.08; p=.02; *d*= 0.4], but didn't differ from responses to concrete words [t(39)= 1.280; SE= 0.09; p=.2; *d*=0.2] (see *Table 4*). No other main effect or interaction reached significance.

Recognition task

All erroneous trials (28,30%) were removed before the analysis of RTs. In the analysis of response times the main effect of the factor *Type of Concept* was significant [F_1 (278) =16.766; MS_e =361529.68; p< .001, n_P^2= .301];[F_2 (2,45) = 4,026; MS_e = 279112,806; p=.02; n_P^2= .152]. From a t-test analysis on paired samples on participants and a t-test analysis for independent samples on materials resulted that abstract words (M= 768.3) were responded to significantly slower than concrete words (M=706.5) [t_1(39)= 2.681; SE= 10.9; p<.001; *d*=0.6][t_2(30)=2.640; SE=21.1; p=.01; *d*=0.9] and also than emotional words (M=740), [t_1(39)=2.495; SE=11.3; p=.01; *d*=0.2], [t_2(30)= 1.578; p>0.5] (see *Table 4*). The main effect of the factor *Effector* also was significant [F_1 (1,39) =11.362; MS_e =461715.085; p< .001, n_P^2= .226] ; [F_2 (1,45) = 24,081; MS_e = 87926,647; p< .001; n_P^2= .349], showing that responses given with the mouth are always slower than those given with the hand. The interaction between *Type of Concept* and *Effector* was not significant. However, the means reveal that the advantage of the Hand over the Mouth responses is less marked with abstract (32 ms) than with both concrete (43 ms) and emotional words (66 ms). Means of response times for *Type of Concept* and *Effector* are shown in *Table 2*.

In the analysis of the accuracy the main effect of the factor *Type of Concept* was significant [F_1 (2,78) = 3.56; MS_e =46.49; *p*=.03, n_P^2= .084];[F_2 (2,45) = 1.33; MS_e =715.96; *p*>.05, n_P^2= .056], (Mean ABS= 1.17; Mean CNC= 0.95; Mean EMO= 1.27). A t-test analysis on paired samples on participants and Effect size (Cohen's d) revealed that concrete words produced less errors than emotional words [t(39)= -2.353; SE=0.13; p=.02; *d*=0.4], and in trend, less errors than abstract words [t(39)= 1.749; SE=0.12; p=.08; *d*= 0.3]. Abstract and emotional words did not differ (p=.3) (see *Table 4*). The interaction between the factors *Type of Concept x Effector* was significant [F_1 (2,78) = 4.89; MS_e =22.43; *p*=.01, n_P^2= .111] [F_2 (2, 45) = 3.883; MS_e = 28,146; *p*=.02; n_P^2=. 147]. T-Student test and Effect size (Cohen's *d*) revealed that emotional words differed in accuracy from both abstract [t_1 (39)=-2.05; SE= 0.13; p=.04; *d*=0.3], [t_2(30)= -1.312; p>.05] and concrete ones [t_1 (39)=-3.14; SE= 0.18; p=.003; *d*=0.6], [t_2 (30)=-2.743; SE=1.04; p=.01; d=0.9]when processed in the mouth condition, producing more errors; abstract and emotional words, when processed in the condition of hand produced significantly more errors than concrete words processed in the condition of mouth [t_1(39)=2.594; SE=0.15; p=.01; *d*=0.5] [t_1(39)= -2.209; SE= 0.14; p=.03; *d*=0.4] in the analysis on participants, but not on materials [p_s<05] (see *Table 5*). Means of errors are showed in *Table 3* and *Figure 4*.

Discussion

The results show that abstract words are processed slower than concrete ones in both lexical decision and recognition. This finding confirm the well-established concreteness effect (Paivio, 1986). As to emotional words, in the lexical decision task they yield more errors than abstract concepts and in the recognition task they yield more errors than concrete concepts and slightly more errors than abstract ones. This result suggests that emotional words cannot be properly assimilated neither to other abstract words nor to concrete ones.

Across the two tasks, responses with the mouth were slower than those with the hand, independently from the concept kind; this effect is not worth discussing since it was likely due to the fact that the button to hold among the teeth was harder to press than the key to press with the hand (see also Borghi and Zarcone, 2016).

As to the relationship of the different words with the hand and mouth effectors, we found no difference in lexical decision task, suggesting that effectors are differently activated only in tasks that require a deeper processing level. The interaction between Kind of concept and Effector was however significant in the recognition task, in the analysis on accuracy. Both abstract and concrete words yielded less errors with mouth than with hand responses, while emotional concepts yielded significantly more errors with mouth than with hand responses. The results thus suggest that abstract words are slightly facilitated with the mouth, as predicted. It is however unclear why this facilitation occurred with concrete words too. The pattern of results of emotional words differed from that of both concrete and abstract concepts – they elicited significantly more errors with mouth than with hand responses.

Experiment 2

A potential problem of Experiment 1 was that the device used to respond to critical trials differed for the mouth and the hand – the fact that the device to hold among the teeth was harder to press

than the button to press with the hands explains why RTs were slower with the mouth responses. Experiment 2 was designed in order to verify whether the findings of Experiment 1 could be replicated also in an experiment in which the mouth and the hand were not the direct response effectors, but were occupied during the task. We therefore introduced catch-trials, to which participants had to respond pressing the button either with the hand or with the mouth. Participants were instead invited to respond to critical trials pressing a pedal with the foot, in order to avoid any potential interference with the hand and mouth effectors. This change had the advantage to allow us to collect response times and errors with the same device.

We intended to test whether abstract, concrete and emotional concepts were differently activated when the mouth and the hand effectors were occupied. We predicted a facilitation of mouth responses with abstract concepts.

Method

Participants

Forty native Italian speakers in a range of age between 20-30 years (22 females and 18 males; mean of age: 23,5; standard deviation of age: 2,12) participated voluntarily. Handedness was assessed using an abridged version of the Edinburgh Inventory (Oldfield, 1971). All participants were Italian native speakers, had normal or corrected-to-normal vision, and were naïve as to the purpose of the experiment. All participants gave written informed consent, and the experimental procedures were approved by the CNR- ISTC ethics committee.

Materials

Materials were the same as Experiment 1, except for 16 catch-trials that were added. Catch-trials were Italian words with a bold letter.

As in Experiment 1, the experiment consisted of two tasks, a lexical decision task and a recognition task, that were presented in sequence; the lexical decision task always preceded the recognition one. Two separate lists of words were created for the two tasks: for the lexical decision task 24 critical words (8 concrete, 8 abstract, 8 emotional), 24 pseudo-words. For the recognition task list, 24 critical words (8 concrete, 8 abstract and 8 emotional), 24 new words.

Procedure

The procedure was the same as that of Experiment 1.

Lexical Decision task

The task was divided into two experimental blocks, each preceded by a training block of 16 trials (8 words and 8 catch-trials). A set of 64 words was presented on the computer screen (24 critical words, 24 pseudo- words and 16 catch-trials). The words were arranged in two different lists, one for each block. Depending on the block, participants were required to keep a button in their dominant hand or in the mouth, between the teeth, and to respond to catch-trials by pressing it; they were instead asked to press the pedal to respond to critical stimuli. The order of the blocks was counterbalanced across participants. Participants were asked to press the pedal if they read an Italian word, and to refrain from responding if the word they read was not an Italian one. They were also required to respond to catch-trials by pressing the button with the hand or mouth,

depending on the condition. Hence the mouth and the hand were not the direct response effectors, but they were occupied during the execution of the task.

Recognition task

The task was divided into two experimental blocks, each preceded by a training block of 8 trials (3 words, 3 new words and 2 catch-trials). A set of 62 words was presented in each block, composed by 24 critical words, 24 new words and 12 catch-trials. The order of the blocks was counterbalanced across participants. Depending on the block, participants were required to keep the button in their dominant hand or in the mouth, between the teeth. As to the critical stimuli, participants were asked to press the pedal in case they recognized that the word on the screen had already been presented in the previous task, or to refrain from responding if the read a new word. When catch-trials were presented, they had to respond by pressing the button with the hand or mouth, depending on the block.

Results

Two 3x2 ANOVAs on RTs and errors were performed for both tasks, one with participants and one with materials as random factor, with factors *Type of Concept* (ABS; CNC; EMO) x *Effector* (mouth; hand). For the participants analyses (indicated by F^1), condition means were obtained by averaging across words, and for the items analyses (indicated by F^2) they were obtained by averaging across participants.

Lexical Decision:

Overall response times were longer than those obtained in Experiment 1, likely due to the presence of catch-trials. All erroneous trials (4,58%) were removed before the analysis of RTs. In the analysis of response times, we found a significant main effect of the *Type of Concept* factor [F_1 (2,78) = 15.941; MS_e =214819.724; p< .001, n_P^2= .290];[F_2 (2,45) = 4.061; MS_e =174855.272; p=.024, n_P^2= .153]. A T-Student test on paired samples on participants and on independent samples on materials and the Effect Size (Cohen's *d*) showed that responses to abstract words were slower than responses to both concrete [t_1(39)=4.175; SE= 7.55; p<.001; *d*= 0.2] [t_2(30)=1.803; SE= 16.908; p=.08; *d*= 0.6] and emotional words [t_1(39)=5.075; SE= 9.01; p<.001; *d*= 0.4] [t_2(30)=2.592; SE= 16.669; p=.01; *d*=0.9] (see *Table 4*); (Mean ABS= 830.2 ms; Mean CNC= 798.7 ms; Mean EMO= 784.5 ms). We found no other significant results [F_s< 1.3], although the trend of the Interaction between *Type of Concept x Effector* factors was in line with the hypothesis, showing that responses to abstract words were slower than both those to concrete and emotional ones, and that only abstract words had a slight advantage when the device was held in the mouth than in the hand, while concrete words and especially emotional ones were faster when processed with the device in the hand. Means are shown in *Table 2*.

In the analysis of the accuracy, the main effect of the *Effector* factor was significant [F_1 (1,39) = 4.24; MS_e =15.33; p=.046; n_P^2= .098;][F_2(1,45)= 5.671; MS_e =33.063; p=.022; n_P^2= .023], showing that responses with the mouth were less accurate than those with the hand (Mean Mouth= 0.45; Mean Hand= 0.28) [t_1 (39)= 2.059; SE= 0.08; p<.05] [t_2(47)=2.406; SE=.173; p=.02; *d*=0.3]. No other main effect or interaction was significant [F_s< .826]. Even if the main effect of *Type of*

Concept was not significant, the percentage of errors was higher with abstract than with emotional and concrete words, in keeping with the results obtained with the RTs and with the well documented concreteness effect (see *Table 3*).

Recognition:

All erroneous trials (35%) were removed before the analysis of RTs. In the analyses on response times, we found a main effect of *Type of Concept* factor on participants [F_1 (2,78) = 3.37; MS_e= 574462.20; *p*=.033; n_P^2=.08] (Mean ABS= 889.11 ms; Mean CNC= 853.98 ms; Mean EMO= 874.10 ms), but not on materials [F_2 (2,45) = 1.7]. A t-test analysis on paired samples and Effect size (Cohen's d) on participants showed that abstract words are significantly slower with respect to concrete words [t(39)= 2.335; SE= 15.04; p=.02; *d*=0.3] (see *Table 4*). In the analysis on materials the interaction between the factors *Type of Concept x Effector* resulted very close to significance [F_2 (2,45) = 3.06; MS_e =306722.753; *p*=.05; n_P^2=.120]. No other significant main effect or interaction were found [F_s<1.47].

In the analyses on accuracy, the predicted significant interaction between *Type of Concept* x *Effector* was found [F_1 (2,78) = 4.35; MS_e =90.258; *p*=.016; n_P^2= .100];[F_2 (2,45) = 4.35; MS_e =68.09; *p*=.019; n_P^2= .162]. A T-test analysis for paired samples and the effect sizes (Cohen's *d*) showed that when participants responded to catch-trials with the mouth, abstract words yielded in tendency more accurate responses than concrete words [t_1 (39)= -1.929; SE= .33; p=.06; *d*= 0.34], while there was no difference with the hand [t_1(39)= -.261; SE= 0.14; p=.8; *d*= -0.03]. Responses to abstract and emotional words did not differ when the mouth was occupied [t_1(39)= -1.29; SE= 0.23; p=.2; *d*= 0.17], while they differed when the hand was occupied [t_1(39)= -2.682; SE=0.27; p=.01; *d*= 0.42], with emotional words producing more errors (Mean ABS-HAND= 2.6; Mean EMO-HAND= 3.3). Moreover, responses to emotional and concrete words differed when given with the hand, with emotional words producing significantly more errors [t_1(39)= -2.783; SE= 0.23; p=.008; *d*= 0.36] (see *Table 5*). A T-test analysis for independent samples on materials revealed that there were no significant differences [F_s<1.13], although responses to emotional words produced in tendency more errors when given with the hand than both abstract [t_2(30)=-1.931; SE=.30; p=.06; d=0.7] and concrete words [t_2(30)=-1.901; SE=.26; p=.06; *d*=0.8]. For abstract and emotional words the recognition was facilitated with the mouth, for concrete ones with the hand. (Mean ABS-M: 2.48; CNC-M:3.13; EMO-M: 2.78); (Mean ABS-H= 2.6; CNC-H= 2.68; EMO-H=3.3). Means of errors are shown in *Table 3* and *Figure 5*.

Discussion

As in Experiment 1, abstract words were processed slower than concrete ones in both lexical decision and recognition tasks. Emotional words were faster than both concrete and abstract concepts in the lexical decision task. Similarly to Experiment 1, our findings confirm the concreteness effect and at the same time suggest that emotional words cannot be properly assimilated neither to other abstract words nor to concrete ones.

As in Experiment 1, we did not find an interaction between Kind of Concept and Effector in the lexical decision task. In the recognition task, instead, the interaction reached significance in the analysis of accuracy. Abstract words yielded less errors in the mouth than in the hand condition, while concrete words yielded less errors in the hand than in the mouth condition, as predicted by the WAT (Words As social Tools) view. Interestingly, emotional words produced results similar to those of abstract words, yielding less errors with the mouth than with the mouth.

General discussion

According to some proposals, abstract concepts evoke more linguistic experience than concrete words (Borghi & Binkofski, 2014; Borghi et al., accepted; Dove, 2011; Gleitman et al., 2005). If the involvement of language activates a motor simulation, this should result in a higher engagement of the mouth effector during processing of abstract than of concrete words. The main aim of this paper was to test the hypothesis that different kind of concepts, i.e. concrete, abstract and emotional ones, differently engaged the mouth and hand effectors. The two experiments implied engaging the mouth and the hand effectors either directly, to provide a response (Experiment 1), or indirectly, keeping them occupied during the response (Experiment 2).

A further aim of this paper was related to the distinction between abstract, concrete and emotional words. Since many authors consider emotional concepts as a subset of abstract concepts while others tend to consider them as independent from both abstract and concrete ones, we intended to verify whether performance with emotional words reflected that with abstract words or not.

Overall, our results confirmed the hypothesis that abstract words involve activation of the mouth, but the effect was modulated by the task and differed depending on whether the response was directly using that effector or not. In the following we will point out the main results, discussing them in light of the advanced hypotheses. We will first illustrate results on the differences in processing the three concept kinds independently of the effector, then we will focus on differences between concepts kinds in relation to the activation of mouth and hand effectors.

Overall processing differences between concept kinds. The effect of *Type of concept* was present in RTs analyses on both experiments and on both tasks: overall, abstract concepts were processed slower than concrete ones (E1 and E2 lexical decision, E1 and E2 recognition) and in Experiment 1 they yielded more errors than emotional concepts in the lexical decision task and slightly more errors than concrete concepts in the recognition task. Our results confirm the well-established concreteness effect (Paivio, 1986; but see exceptions to the effect when controlling stimuli for valence: Kousta et al., 2011; Barca et al., 2002), that shows that abstract words are slower than concrete ones, and extended it showing that in the lexical decision task they are also slower than emotional words (see also Ponari et al., 2017).

As to emotional words, our results cast doubts on the assimilation of emotional to abstract concepts: across experiments and tasks, the pattern of responses elicited by emotional words differed from that of abstract words and occasionally from that of concrete words too. In the lexical decision task of both experiments emotional words were processed faster than abstract words and did not differ from concrete words. Our results are in line with those of a study by Siakaluk et al. (2016) showing that valenced words were processed faster than other words in lexical decision task. As to accuracy, in Experiment 1 responses to emotional concepts were also more accurate than abstract words in lexical decision and less accurate than concrete ones in recognition. Overall, emotional words differed in processing from both concrete and abstract concepts, confirming the views according to which they represent a third kind of concept (Altarriba et al., 1999; Setti and Caramelli, 2005).

Processing differences between concept kinds in relation to the effectors.

The experiments we designed were driven from the hypothesis that abstract concepts would activate more the mouth motor system. Furthermore, we wanted to explore whether the two effectors, mouth and hand, would be differently activated with emotional words. We thus expected to find a *Type of Concept x Effector* interaction.

If we consider lexical decision, in neither experiment the predicted Type of Effector x Concept interaction was significant. Results thus seemed to suggest that the lexical decision task did not lead to a differential activation of the hand and mouth effectors, likely because of the superficial processing level it implied.

The results consistently differed if we consider the Recognition task. The interaction was not significant in RTs, but it reached significance in accuracy in both experiments. Notice that, differently than in the lexical decision task, in recognition tasks accuracy is a more important measure compared to RTs also because of the high percentage of recognition errors. In Experiment 1, in which hand and mouth were the direct response effectors, abstract concepts were slightly facilitated with the mouth, as predicted. It was however unclear why this facilitation occurred with concrete words too. In Experiment 2, in which the hand and mouth were occupied but responses were provided in the same manner, pressing a pedal with the foot, responses to abstract words were the most accurate ones in the mouth condition; they were significantly more accurate than responses to concrete words, while in the hand condition the accuracy of abstract and concrete words did not differ. These results clearly confirm our hypothesis, indicating that abstract words were facilitated when the mouth was activated, and extend previous results, showing that such a facilitation occurred not only when the mouth was the direct response effector but also when the mouth was occupied with a device.

This confirms the predictions of the WAT proposal, according to which abstract concepts re-enact linguistic and social experience more than concrete concepts, hence determining a higher activation of the mouth. Three possible mechanisms can underline this activation (see for further discussion Borghi & Zarcone, 2016; Borghi et al., accepted): a. the re-enactment of the acquisition experience, which is mainly linguistic and occurs in a social context; b. the inner speech used to re-explain to us the meaning of abstract concepts; c. the meta-cognitive awareness that our conceptual knowledge is inadequate followed by the motor preparation to ask to others information on words meaning (social-metacognition, Borghi et al., accepted). The present study does not allow us to determine which of the three mechanisms is responsible of the effects; further research is needed in order to disentangle them.

The pattern of emotional concepts was, instead, more fluctuating across the two experiments. In the recognition task of Experiment 1 emotional words had a disadvantage in the mouth condition, differently from abstract words. Conversely, in the same task of Experiment 2, emotional words showed a disadvantage in the hand condition, producing less errors with the mouth. One could argue that the effect is due to interference with emotional concepts when the effector of response is the mouth, and to facilitation when it is not. We do not favor this interpretation, though, for a couple of reasons. First, the result of Experiment 2 reveal that the difference between emotional concepts and the other concepts concerns the hand responses, not the mouth ones, rendering the hypothesis of a facilitation with the mouth really unlikely. Second, previous results with abstract not emotional concepts showed that responding with the mouth provoked a facilitation, not an interference (Borghi & Zarcone, 2016). Finally, the variable pattern of activation of the hand and

mouth effectors with emotional words is in keeping with recent experimental results. Ratings results showed that emotional concepts activate both the mouth and the hand effectors, while mental states concepts activate more selectively the mouth (Ghio et al., 2013), andfMRI results clearly demonstrated that while the face/mouth motor system in the brain is more activated by more pure abstract concepts as mental state concepts than by emotional ones, which activate hand and face motor cortex to similar degrees (Dreyer and Pulvermuller, 2017). Overall, this finding is in line with views according to which emotions represent a third kind of concepts, structurally different from both concrete and abstract ones (see Barca et al., 2017, and Mazzuca et al., 2017, for further discussion), and with the proposal according to which emotional concepts, being more grounded than other abstract concepts, provide a bootstrapping mechanism to learn them (Ponari et al., 2017).

While we found that abstract concepts processing was facilitated with the mouth, the results are less marked than in a previous study (Borghi and Zarcone, 2016). We ascribe this difference to two factors: first, to the fact that in the previous study participants were provided with a context and not only with single words, and second, to the fact that the task was a deep processing one.

The present study adds important information to previous studies on concepts and effector activation: it suggests that the mouth and hand effectors can be differently activated depending on the task and on the depth level it implies. The different effectors did not influence results in the lexical decision task, but they had an impact on a subsequent recognition task.

Conclusion

Overall, our studies show that, in general, abstract words are more difficult to process, as revealed by the slower RTs, independently from the task. This confirms the concreteness effect, well-established in the literature. Across the tasks and experiments, emotional concepts had instead a fluctuating pattern. This suggests that they are markedly different from both concrete and abstract concepts.

If we consider the relationship between concepts and effectors, we confirmed the hypothesis proposed by the WAT proposal that abstract concepts had an advantage in the mouth condition. The result was however modulated by the task: the effectors did not have a different effect on concepts in a lexical decision task, but impacted a subsequent recognition task. Overall, our findings highlight that concepts are grounded and activate bodily experiences, but they also point out the exquisitely flexible character of our conceptual representation.

Acknowledgments

Thanks to Michele Marzocchi for programming the experiment and helping us in planning the experimental details.

References

Altarriba, J., Bauer, L. M., & Benvenuto, C. (1999). Concreteness, context availability, and imageability ratings and word associations for abstract, concrete, and emotion words. *Behavior Research Methods, Instruments, & Computers, 31*(4), 578-602.

Altarriba, J., Bauer, L.M. (2004).The distinctiveness of emotion concepts: a comparison between emotion, abstract, and concrete words. *American Journal of Psychology, 117*(3), 389–410. doi: 10.2307/4149007.

Barca, L., Burani, C., & Arduino, L. S. (2002). Word naming times and psycholinguistic norms for Italian nouns. *Behavior Research Methods, Instruments, & Computers*, *34*(3), 424-434.

Barca, L., Mazzuca, C., Borghi, A.M. (2017). Pacifier use and conceptual relations of abstract and emotional concepts. *Front. Psychol*. 8:2014. doi: 10.3389/fpsyg.2017.02014.

Barsalou, L. W. (2003). Abstraction in perceptual symbol systems. *Philosophical Transactions of the Royal Society B: Biological Sciences*, *358*(1435), 1177-1187.

Barsalou, L. W. (2008). Grounded cognition. *Annu. Rev. Psychol.*, *59*, 617-645.

Barsalou, L. W. (2010). Grounded cognition: Past, present, and future. *Topics in cognitive science*, *2*(4), 716-724.

Barsalou, L.W. (2016). On staying grounded and avoiding quixotic dead ends. *Psychonomic Bulletin & Review, 23*, 1–21.

Borghi, A.M., Caruana, F. (2015). Embodiment Theory. In: James D. Wright (editor-in-chief), *International Encyclopedia of the Social & Behavioral Sciences*,2nd edition, Vol 7. Oxford: Elsevier. pp. 420-426. ISBN: 978008097086.

Borghi, A. M., Flumini, A., Cimatti, F., Marocco, D., & Scorolli, C. (2011). Manipulating objects and telling words: a study on concrete and abstract words acquisition. *Frontiers in psychology*, *2*, 15.

Borghi, A. M., & Binkofski, F. (2014). *Words As social Tools: An embodied view on abstract concepts*. New York: Springer.

Borghi, A. M., Binkofski, F., Castelfranchi, C., Cimatti, F., Scorolli, C., & Tummolini, L. (2017). The challenge of abstract concepts. *Psychological Bulletin*, *143*(3), 263.

Borghi, A. M., & Cimatti, F. (2009, January). Words as tools and the problem of abstract word meanings. In *Proceedings of the Annual Meeting of the Cognitive Science Society* (Vol. 31, No. 31).

Borghi, A.M., Barca, L., Binkofski, F., Tummolini, L. (accepted). Abstract concepts, language and sociality: from acquisition to inner speech. *Philosophical Transactions of the Royal Society B: Biological Sciences.*

Borghi, A. M., & Zarcone, E. (2016). Grounding abstractness: abstract concepts and the activation of the mouth. *Frontiers in psychology*, *7*, 1498.

Buccino, G., Riggio, L., Melli, G., Binkofski, F., Gallese, V., & Rizzolatti, G. (2005). Listening to action-related sentences modulates the activity of the motor system: A combined TMS and behavioral study. *Cognitive Brain Research*, *24*(3), 355-363.

Cappa, S. F., & Pulvermüller, F. (2012). Cortex special issue: Language and the motor system. *Cortex*, *48*(7), 785-787.

Clark, A. (1998). Magic words: How language augments human computation. Language and thought: Interdisciplinary themes, 162–183.

Connell, L., Lynott, D., & Carney, J. (2017). Interoception: The Forgotten Modality in Perceptual Grounding of Concepts. *Proceedings of Cognitive Science Society.*

Connell, L., Lynott, D., & Banks, B. (accepted). Interoception: The forgotten modality in perceptual
grounding of abstract and concrete concepts. *Philosophical Transactions of the Royal Society B: Biological Sciences.*

Crutch, S. J., Troche, J., Reilly, J., & Ridgway, G. R. (2013). Abstract conceptual feature ratings: the role of emotion, magnitude, and other cognitive domains in the organization of abstract conceptual knowledge. *Frontiers in human neuroscience*, *7*.

Cuccio, V., & Gallese, V. (accepted). A Peircean account of concepts.
Grounding abstraction in phylogeny through a comparative neuroscientific perspective. *Philosophical Transactions of the Royal Society B: Biological Sciences*.

Della Rosa, P. A., Catricalà, E., Vigliocco, G., & Cappa, S. F. (2010). Beyond the abstract—concrete dichotomy: Mode of acquisition, concreteness, imageability, familiarity, age of acquisition, context availability, and abstractness norms for a set of 417 Italian words. *Behavior research methods, 42*(4), 1042-1048.

Dove, G. (2009). Beyond Perceptual symbols: a call for representational pluralism. *Cognition*, 110, 412-31.

Dove, G. (2011). On the need for embodied and disembodied cognition. *Frontiers in Psychology*, 1, 242.

Dove, G. (2014). Thinking in words: language as an embodied medium of thought. *Topics in cognitive science, 6*(3), 371-389.

Dove, G. (2015). How to go beyond the body: an introduction. *Frontiers in psychology*, *6*, 660.

Dove, G. (accepted). Language as a Disruptive Technology: Abstract Concepts, Embodiment, and the Flexible Mind. *Philosophical Transactions of the Royal Society B: Biological Sciences.*

Dreyer, F. R., Frey, D., Arana, S., von Saldern, S., Picht, T., Vajkoczy, P., & Pulvermüller, F. (2015). Is the motor system necessary for processing action and abstract emotion words?

Evidence from focal brain lesions. *Frontiers in Psychology*, *6*.

Dreyer, F. R., & Pulvermüller, F. (2017). Abstract semantics in the motor system?–An event related fMRI study on passive reading of semantic word categories carrying abstract emotional and mental meaning. *Cortex*.

Ghio, M., Vaghi, M. M. S., & Tettamanti, M. (2013). Fine-Grained Semantic Categorization across the Abstract and Concrete Domains. *PLoS ONE*, *8*(6). https://doi.org/10.1371/journal.pone.0067090

Gleitman, L. R., Cassidy, K., Nappa, R., Papafragou, A., & Trueswell, J. C. (2005). Hard words. *Language Learning and Development, 1*(1), 23-64.

Glenberg, A. M. (2015). Few believe the world is flat: How embodiment is changing the scientific understanding of cognition. *Canadian Journal of Experimental Psychology/Revue canadienne de psychologie expérimentale*, *69*(2), 165.

Glenberg, A. M., & Gallese, V. (2012). Action-based language: A theory of language acquisition, comprehension, and production. *cortex*, *48*(7), 905-922.

Glenberg, A. M., Witt, J. K., & Metcalfe, J. (2013). From the revolution to embodiment: 25 years of cognitive psychology. *Perspectives on Psychological Science*, *8*(5), 573-585.

Granito, C., Scorolli, C., & Borghi, A. M. (2015). Naming a Lego World. The Role of Language in the Acquisition of Abstract Concepts. *PloSone, 10*(1), e0114615.

Hauk, O., Johnsrude, I., & Pulvermüller, F. (2004). Somatotopic representation of action words in human motor and premotor cortex. *Neuron*, *41*(2), 301-307.

Kousta, S. T., Vigliocco, G., Vinson, D. P., Andrews, M., & Del Campo, E. (2011). The representation of abstract words: why emotion matters. *Journal of Experimental Psychology: General*, *140*(1), 14.

Lupyan, G., & Clark, A. (2015). Words and the World Predictive Coding and the Language-Perception-Cognition Interface. *Current Directions in Psychological Science, 24*(4), 279-284.

Mazzuca, C., Barca, L., & Borghi, A. M. (2017). The Peculiarity of Emotional Words: A Grounded Approach. *Rivista internazionale di Filosofia e Psicologia*, *8*(2), 124-133.

Mellem, M. S., Jasmin, K. M., Peng, C., & Martin, A. (2016). Sentence processing in anterior superior temporal cortex shows a social-emotional bias. *Neuropsychologia*, *89*, 217-224.

Newcombe, P. I., Campbell, C., Siakaluk, P. D., & Pexman, P. M. (2012). Effects of emotional and sensorimotor knowledge in semantic processing of concrete and abstract nouns. *Frontiers in human neuroscience*, *6*.

Oldfield, R. C. (1971). The assessment and analysis of handedness: the Edinburgh inventory. *Neuropsychologia*, *9*(1), 97-113.

Paivio, A. (1986). *Mental Representations: A Dual Coding Approach*. Oxford, UK: Oxford University Press.

Pecher, D., Boot, I., van Dantzig, S. (2011). Abstract concepts: sensory motor grounding, metaphors, and beyond. In B. Ross (Ed.), *The Psychology of Learning and Motivation*, Vol. 54, 217-48. Burlington: Academic Press.

Ponari, M., Norbury, C. F., & Vigliocco, G. (2017). Acquisition of abstract concepts is influenced by emotional valence. *Developmental Science*.

Prinz, J. J. (2012). Beyond human nature. How culture and experience shape our lives.London; New York, NY: Penguin.

Pulvermüller, F. (2005). Brain mechanisms linking language and action. *Nature Reviews Neuroscience*, *6*(7), 576.

Recchia, G., & Jones, M. N. (2012). The semantic richness of abstract concepts. *Frontiers in human neuroscience, 6.*

Roversi, C., Borghi, A. M., & Tummolini, L. (2013). A marriage is an artefact and not a walk that
we take together: An experimental study on the categorization of artefacts. *Review of Philosophy and Psychology, 4*(3), 527–542.

Setti, A., Caramelli, N. (2005) Different domains in abstract concepts. In B. Bara, B. Barsalou, M. Bucciarelli (Eds.). *Proceedings of the XXVII Annual Conference of the Cognitive Science*. Mahwah NJ: Erlbaum.

Siakaluk, P. D., Newcombe, P. I., Duffels, B., Li, E., Sidhu, D. M., Yap, M. J., & Pexman, P. M. (2016). Effects of Emotional Experience in Lexical Decision. *Frontiers in psychology, 7*, 1157.

Thill, S., & Twomey, K. E. (2016). What's on the inside counts: A grounded account of concept acquisition and development. *Frontiers in psychology, 7*.
Tomasino, B., & Rumiati, R. I. (2013). Introducing the special topic “The when and why of sensorimotor processes in conceptual knowledge and abstract concepts”. *Frontiers in human neuroscience*, 7.

Topolinski, S., & Strack, F. (2009). Motormouth: mere exposure depends on stimulus-specific motor simulations. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *35*(2), 423.

Topolinski, S., Maschmann, I. T., Pecher, D., & Winkielman, P. (2014). Oral approach–avoidance: Affective consequences of muscular articulation dynamics. *Journal of personality and social psychology*, *106*(6), 885.

Wang, X., Wu, W., Ling, Z., Xu, Y., Fang, Y., Wang, X., ... & Bi, Y. (2017). Organizational Principles of Abstract Words in the Human Brain. *Cerebral Cortex*, 1-14.

Wauters, L. N., Tellings, A. E., Van Bon, W. H., & Van Haaften, A. W. (2003). Mode of acquisition of word meanings: The viability of a theoretical construct. *Applied Psycholinguistics, 24*(03), 385-406.