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

Claudia Mazzuca [Corresp., 1] , Luisa Lugli [1] , Roberto Nicoletti [1] , Anna M Borghi [Corresp. 2, 3]

[1] Department of Philosophy and Communication, University of Bologna, Bologna, Italy

[2] Department of Dynamic and Clinical Psychology, University of Roma "La Sapienza", Rome, Italy

[3] Institute of Cognitive Sciences and Technologies, Italian National Research Council, Rome, Italy

Corresponding Authors: Claudia Mazzuca, Anna M Borghi
Email address: mazzuca.claudia@gmail.com, anna.borghi@gmail.com

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.

1

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

4
5

6   Claudia Mazzuca[1], Luisa Lugli[2], Roberto Nicoletti[3], Anna M. Borghi[4,5]
7   [1] Department of Philosophy and Communication, University of Bologna, Italy
8   [2] Department of Philosophy and Communication, University of Bologna, Italy
9   [3] Department of Philosophy and Communication, University of Bologna, Italy
10 [4] Department of Dynamic and Clinical Psychology, Sapienza University of Rome, Italy
11 [5] Institute of Cognitive Sciences and Technologies, Italian National Research Council, Rome,
12 Italy
13
14 Corresponding Author:
15 Anna M. Borghi[4,5]
16 Via dei Marsi 78, Rome, 00185, Italy
17 Via San Martino della Battaglia 44, Rome, 00185, Italy
18 anna.borghi@gmail.com
19 Claudia Mazzuca[1]
20 Via Azzo Gardino 23, Bologna, 40122, Italy
21 Email address: mazzuca.claudia@gmail.com, claudia.mazzuca2@unibo.it
22

23
24 **Introduction**
25
26 When we process and recognize words, do we activate the body? Do different kinds of words, as
27 abstract, concrete and emotional words, activate different effectors, as the mouth and the hand? Is
28 this eventual activation modulated by the task?
29 The last years have seen the widespread of embodied and grounded (from now on grounded)
30 theories of cognition (Barsalou, 2008, 2010, 2016; Glenberg, 2015; Glenberg et al., 2013; Borghi
31 & Caruana, 2015), according to which concepts and words activate our bodily interactions with
32 the world. A lot of compelling evidence has demonstrated that when we hear words as for example
33 'ball' we re-enact previous interactions with the word referent, activating the sensorimotor system.
34 This is particularly true for words that refer to object or actions (Cappa & Pulvermueller, 2012;
35 Glenberg & Gallese, 2012).
36
37 Explaining how also abstract concepts and words, as "fantasy" and "beauty", are grounded in the
38 sensorimotor system, represents a major challenge for embodied and grounded views, as recent
39 debates testify (for recent reviews, see Borghi et al., 2017; Pecher et al., 2011; Wang et al., 2017;
40 for special topics see Tomasino & Rumiati, 2013, Frontiers in Human Neuroscience; Dove, 2015,
41 Frontiers in Psychology; Mahon & Hickok, 2016, Psychonomic Bulletin & Review; Bolognesi et
42 al., Topics in Cognitive Science, in press; Borghi, Barca, Binkofski & Tummolini, Philosophical
43 Transactions of the Royal Society B, in press).
44 Compared to concrete words, abstract words typically lack a single object as referent, they refer to
45 more complex events and situations (Barsalou, 2003), they are more detached from the five
46 sensorial modalities, they are represented in a more variable way, and they are generally more
47 grounded in internal states (interoception, proprioception) (Connell et al., 2017, accepted; Borghi
48 et al., accepted) (Borghi & Binkofski, 2014).
49
50 Two major novelties characterize recent literature on abstract concepts.
51 The first novelty is represented by the recognition that abstract concepts are not a monolithic
52 whole, but that there might exist sub-kinds of abstract concepts, that are differently represented.
53 To date some studies are starting to explore the differences between abstract concepts as
54 mathematic ones, emotional ones, mental states ones, social concepts, temporal concepts (e.g. Setti
55 & Caramelli, 2005; Ghio et al., 2003; Roversi et al., 2013; Crutch et al., 2013; Mellem et al., 2016;
56 Villani, Lugli, Liuzza & Borghi, in preparation; Borghi et al., accepted). In this framework, it is
57 debated whether emotions are to be considered as a sub-kind of abstract concepts or whether they
58 differ from both concrete and abstract ones (for discussion see Mazzuca et al., 2017; Barca et al.,
59 2017). Altarriba et al. (1999) and Altarriba and Bauer (2004) demonstrated that emotional concepts
60 differ from concrete and abstract ones in ratings on a variety of psycholinguistics criteria, as
61 concreteness, imageability, and contextual availability, that they elicit different word associations,
62 and that in free recall they are recalled better than concrete and abstract concepts. They have even
63 argued that including emotional concepts among abstract concepts can lead to biased results
64 (Altarriba et al., 1999).
65 For this reason in the present work we will consider abstract, concrete and emotional concepts,
66 separately in order to verify whether emotional concepts are responded to more similarly to
67 concrete or to abstract concepts. The first aim of the present experiment thus consists in comparing
68 processing of abstract, concrete and emotional concepts in a lexical decision task and in a

69 subsequent recognition task, in order to verify whether they are differently grounded in the
70 sensorimotor system, differently activating the hand and mouth effectors.
71
72 The second novelty in current literature is the emergence of multiple representation views (Borghi
73 & Binkofski, 2014; Cuccio & Gallese, accepted; Dove, 2009, 2011; Dreyer & Pulvermuller, 2017;
74 Kousta et al., 2011; Newcombe et al., 2012; Prinz, 2012; Recchia & Jones, 2012). These views
75 represent an extension of grounded ones; they contend that, in order to fully account for abstract
76 concepts representation, other systems (linguistic, emotional) beyond the perception and action
77 systems are likely activated. Among these views, some proposals highlight the importance of
78 language for abstract concepts representation. According to WAT (Words As social Tools)
79 proposal (Borghi et al., accepted; Borghi & Binkofski, 2014; Borghi et al., 2011; Borghi & Cimatti,
80 2009; Borghi & Zarcone, 2016), words are tools useful to operate in the physical and social
81 environment. Specifically, abstract words would evoke linguistic and social experience more than
82 other words, because they are more complex, more detached from sensorial modalities, and more
83 variable. Indeed, linguistic labels facilitate us in forming categories composed by heterogeneous
84 exemplars, as those of abstract concepts, and inner speech can help us either to retrieve the
85 linguistically conveyed information we received during word acquisition, to re-explain to
86 ourselves the word meaning or to prepare ourselves to ask to others information on the word
87 meaning. In a similar vein, Dove (2014) has proposed that language is useful to improve our
88 thought and our problem solving abilities (see also Clark, 1998; Lupyan & Clark, 2015; Dove,
89 accepted). Consistently with this perspective, literature on Modality of Acquisition
90 (MoA)(Wauters, 2003) has shown that words acquired through the linguistic rather than the
91 perceptual modality, i.e. pointing to their referent, are more abstract and acquired later (see also
92 Thill & Thomey, 2016).
93
94 In a grounded perspective, the activation of language would involve the body, and particularly the
95 mouth motor effector. Studies by Topolinski and collaborators (Topolinski and Strack, 2009;
96 Topolinski et al., 2014) have shown that during word reading we activate a simulation of the
97 phono-articulatory aspects of words; here we hypothesize that this simulation is stronger in the
98 case of abstract words, because for them language is particularly relevant.
99
100 The second and more important aim of our study is thus to test the hypothesis that processing
101 different kinds of words differently activate the body, involving the mouth and the hand effectors.
102 More specifically, we predict the mouth motor system is more engaged for abstract than for
103 concrete words, due to the fact that abstract concepts activate more linguistic experience.
104 Consistently, previous evidence with has shown that abstract words are rated as involving the
105 mouth more than concrete words (Granito et al., 2015), and that abstract sentences referring to
106 mental states and to emotions are rated as involving the mouth more than math-related abstract
107 sentences (Ghio et al., 2013). Furthermore, behavioral evidence with response times have
108 demonstrated that responses with the mouth were facilitated with abstract compared to concrete
109 concepts in a definition-word-matching task (Borghi & Zarcone, 2016), and recent fMRI evidence
110 has shown that abstract concepts evoke the mouth motor system (Dreyer et al., 2015; Dreyer &
111 Pulvermuller, 2017).
112
113 We intend here to investigate whether the facilitation of mouth responses with abstract concepts
114 is present also in a task implying a rather superficial processing level, as the lexical decision task,

115 and to verify whether it affects recognition. Notably, previous evidence on activation of effectors
116 with verbs was obtained not only with sentences or verbs evaluation tasks (e.g. Buccino et al.,
117 2005;), but also with lexical decision tasks (e.g. Hauk et al., 2004).
118
119 To investigate the involvement of the mouth effector in the processing of abstract words compared
120 to concrete and emotional ones, we performed two different experiments. In Experiment 1
121 participants responded by pressing a button with the hand or with the mouth, in Experiment 2 they
122 kept a button in the hand or in the mouth to respond to catch-trials, but responses to critical trials
123 were given pressing a pedal with the foot.
124

Experiment 1

126
127 Previous results in which participants were required to decide whether a definition matched with
128 a target words revealed that processing of abstract concepts were facilitated with mouth responses,
129 while processing of concrete ones with manual responses (Borghi & Zarcone, 2016). In
130 Experiment 1 we used the same response modality and the same response devices adopted by
131 Borghi and Zarcone. We intended to verify whether the facilitation of abstract over concrete
132 concepts in responses with the mouth was present also in a task involving a more superficial
133 processing level, i.e. a lexical decision task, and in a subsequent recognition task. As to emotional
134 words, we were interested in investigating whether they were processed similarly to other abstract
135 words or whether they differed from both concrete and abstract words.
136

Method
Participants
139 Forty native Italian speakers in a range of age between 20-30 years (22 females and 18 males;
140 mean age: 20,1; standard deviation of age: 2,12) participated voluntarily. Handedness was assessed
141 using an abridged version of the Edinburgh Inventory (Oldfield, 1971). All participants were
142 Italian native speakers, had normal or corrected-to-normal vision, and were naïve as to the purpose
143 of the experiment. All participants gave written informed consent, and the experimental procedures
144 were approved by the CNR- ISTC ethics committee.
145

Materials
147
148 We selected 90 Italian words from the Della Rosa et al. database (Della Rosa et al., 2010),
149 composed by 30 concrete words, 30 abstract and 30 words that according to the experimenters had
150 high emotional valence. The selected words were balanced in Familiarity (mean of FAM: 590; *SD*:
151 148.09). We considered the dimensions of concreteness and abstractness as distinctive for concrete
152 words (mean of CNC: 648.08; mean of ABS: 178.31) and abstract words (mean of CNC: 209.68;
153 mean of ABS:547.92); the emotional words we chose had the following values of abstractness and
154 concreteness (mean of CNC: 343.09; mean of ABS: 408.09).
155 To verify the emotional valence of words an on-line pre-test was accomplished; we asked 26
156 participants (14 females and 12 males) to judge the emotional value of each word on a 7-points
157 Likert scale (1 was rated as non-emotional and 7 as completely emotional). Since in the literature
158 it is debated whether emotional words can be considered a subset of abstract concepts or represent
159 a kind of concepts different from both concrete and abstract concepts (Altarriba et al.,1999; Kousta

160   et al., 2011), the pre-test also aimed to clearly distinguish abstract, concrete and emotional words,
161   avoiding overlaps between abstract and emotional words.
162   Among the original 90 words we selected 48 words composed by 16 concrete, 16 abstract, and 16
163   emotional words: the average emotional valence of the selected words was 2.13 for concrete words,
164   4.54 for emotional words and 3.63 for abstract words. We performed a T Student test for
165   independent samples and we calculated the effect size (Cohen's d), in order to verify if concrete,
166   abstract and emotional words differed in Concreteness; all the categories (ABSTRACT,
167   CONCRETE and EMOTIONAL) resulted to differ in Concreteness ($p_s < .001$; abstract and
168   concrete's $d= 12.82$; abstract and emotional's $d= 2.65$; concrete and emotional's $d= 10.82$). The
169   abstract and concrete selected words also differed in Imageability, Age of Acquisition, Contextual
170   Availability, Abstractness, Modality of Acquisition and only slightly in Number of Letters
171   (respectively, Imageability t (30) = -18.4, $p <.001$, $d= 6.52$; Age of Acquisition t (30) = 7.3, $p <.00$,
172    $d= 2.60$; Contextual Availability, t (30)=-11.7, $p <.001$, $d= 4.15$; Abstractness, t (30)= 23.7, p
173    $<.001$, $d= 0.92$; Modality of Acquisition, t (30)= 10.03, $p <.001$, $d= 3.54$; Number of Letters, t
174   (30)= 3.3, $p <.05$, $d= 3.72$). They did not differ in Familiarity (t (30)= .1, $p =.9$, $d= 0.04$). The
175   abstract and emotional selected words resulted to differ in Imageability, Age of Acquisition,
176   Contextual Availability, Abstractness and Modality of Acquisition (respectively, Imageability t
177   (30) = -3.9, $p <.001$, $d= 1.39$; Age of Acquisition t (30)= 3.1, $p =.004$, d= 1.11; Contextual
178   Availability, t (30)=-3.7, $p <.001$, $d= 1.31$; Abstractness, t (30)= 4.8, $p <.001$, $d= 1.70$; Modality
179   of Acquisition, t (30)= 3.4, $p =.002$, $d= 1.20$), while they did not differ in Familiarity and Number
180   of Letters (Familiarity: t (30)=.1, $p =.9$, $d= 0.04$; Number of Letters: t (30)=1.2, $p =.2$, $d= 0.42$).
181   As regards concrete and emotional selected words, they differed in Imageability, Age of
182   Acquisition, Contextual Availability, Abstractness, Modality of Acquisition and Number of
183   Letters (respectively, Imageability t (30) = 17.7, $p <.001$, $d= 6.26$; Age of Acquisition t (30)= -4.4,
184    $p <.001$, $d= 1.59$; Contextual Availability, t (30)=7.9, $p <.001$, $d= 2.80$; Abstractness, t (30)= -
185   28.2, $p <.001$, $d= 9.97$; Modality of Acquisition, t (30)= -6.6, $p <.001$, $d= 2.34$; Number of Letters,
186   t (30)= -2.3, $p =.02$, $d= 0.81$), while they did not differ in Familiarity (t (30)= .005, $p =.9$, $d= 0.00$).
187   Abstract and emotional words differed from concrete ones in Frequency ($p_s<.05$, abstract and
188   concrete $d= 3.83$, emotional and concrete $d= 4.78$). Means of Frequency and number of letters are
189   presented in *Table 1*. Emotional and abstract words did not differ ($p=1$, $d= 0.95$); concrete words
190   differed from abstract ones in Number of Syllables ($p<.05$, $d= 5.23$), while emotional words did
191   not differ neighter from concrete nor from abstract words ($p_s>.05$, emotional and concrete's $d=$
192   3.33, abstract and emotional's $d= 1.89$).
193   We subsequently added 48 pseudowords, created by modifying one letter at the beginning, in the
194   middle or at the end of concrete, abstract and emotional words in the same proportion as the critical
195   words. Then we created 24 words to be used as catch-trials: they were Italian words with a bold
196   letter, at the beginning, in the middle or at the end of the word. Finally we selected other 24 new
197   words, maintaining the proportion between abstract, concrete and emotional words for the
198   recognition task. Words that can directly activate hand or mouth (e.g. tools or food related words)
199   were excluded from the list. Stimuli are shown in *Table 1*.
200   The experiment consisted of two tasks, a lexical decision task and a recognition task, that were
201   presented in sequence; the lexical decision task always preceded the recognition one. Two separate
202   lists of words were created for the two tasks: for the lexical decision task 24 critical words (8
203   concrete, 8 abstract, 8 emotional), and 24 pseudo-words. For the recognition task list, 24 critical
204   words (8 concrete, 8 abstract and 8 emotional) and 24 new words were used.
205

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

252 performed without the factor Congruency. For the participants analyses (indicated by F^1),
253 condition means were obtained by averaging across words, and for the items analyses (indicated
254 by F^2) they were obtained by averaging across participants.
255
256

257 *Lexical Decision task*

258

259 All erroneous trials (2,96%) were removed before the analysis of RTs. In the analysis of response
260 times both the main effect of the factor *Type of Concepts* [F_1 (2,78) = 27.29; MS_e =140794.106;
261 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
262 of the factor *Effector* were significant [F_1 (1,39) = 31.129; MS_e =261172.157; p< .001, n_P^2= .444];
263 [F_2 (1,45) = 19.581; MS_e =198796.043; p< .001; n_P^2= .303]. A t-test analysis for paired samples
264 and the Effect size (Cohen's *d*) on participants and a t-test analysis for independent samples on
265 materials revealed that abstract words were responded to slower than both concrete [t_1(39)= 6.375;
266 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)=
267 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
268 participants: ABS: 715.5; CNC:671.7; EMO: 672.3). (means materials A: 730,9 ms; C: 672,3 ms;
269 E: 674,7 ms). The *Effector* effect was due to the faster response times with the Hand, likely due to
270 the higher difficulty in pressing the device with the mouth (see also Borghi & Zarcone, 2016). The
271 interaction between the factors *Type of Concept* x *Effector* didn't reach significance [*p*=.82];the
272 means of RTs are shown in *Table 2*.

273

274 In the analysis on the accuracy the main effect of the factor *Type of Concept* was significant [F_1
275 (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]
276 (Mean ABS= 0.3; Mean CNC=0.2; Mean EMO= 0.1); means of errors are shown in *Table 3*. A t-
277 test analysis on paired samples and Effect size (Cohen's *d*) revealed that responses to abstract
278 words produced significantly more errors than responses to emotional words [t(39)= 2.379;
279 SE=0.08; p=.02; *d*= 0.4], but didn't differ from responses to concrete words [t(39)= 1.280; SE=
280 0.09; p=.2; *d*=0.2] (see *Table 4*). No other main effect or interaction reached significance.

281

282 *Recognition task*

283

284 All erroneous trials (28,30%) were removed before the analysis of RTs. In the analysis of response
285 times the main effect of the factor *Type of Concept* was significant [F_1 (278) =16.766; MS_e
286 =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
287 a t-test analysis on paired samples on participants and a t-test analysis for independent samples on
288 materials resulted that abstract words (M= 768.3) were responded to significantly slower than
289 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;
290 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],
291 [t_2(30)= 1.578; p>0.5] (see *Table 4*). The main effect of the factor *Effector* also was significant [F_1
292 (1,39) =11.362; MS_e =461715.085; p< .001, n_P^2= .226] ; [F_2 (1,45) = 24,081; MS_e = 87926,647;
293 p< .001; n_P^2= .349], showing that responses given with the mouth are always slower than those
294 given with the hand. The interaction between *Type of Concept* and *Effector* was not significant.
295 However, the means reveal that the advantage of the Hand over the Mouth responses is less marked
296 with abstract (32 ms) than with both concrete (43 ms) and emotional words (66 ms). Means of
297 response times for *Type of Concept* and *Effector* are shown in *Table 2*.

298
299
300
301 In the analysis of the accuracy the main effect of the factor *Type of Concept* was significant [F_1
302 (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],
303 (Mean ABS= 1.17; Mean CNC= 0.95; Mean EMO= 1.27). A t-test analysis on paired samples on
304 participants and Effect size (Cohen's d) revealed that concrete words produced less errors than
305 emotional words [t(39)= -2.353; SE=0.13; p=.02; *d*=0.4], and in trend, less errors than abstract
306 words [t(39)= 1.749; SE=0.12; p=.08; *d*= 0.3]. Abstract and emotional words did not differ (p=.3)
307 (see *Table 4*). The interaction between the factors *Type of Concept x Effector* was significant [F_1
308 (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].
309 T-Student test and Effect size (Cohen's d) revealed that emotional words differed in accuracy from
310 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
311 [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
312 in the mouth condition, producing more errors; abstract and emotional words, when processed in
313 the condition of hand produced significantly more errors than concrete words processed in the
314 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;
315 *d*=0.4] in the analysis on participants, but not on materials [p_s<05] (see *Table 5*). Means of errors
316 are showed in *Table 3* and *Figure 4*.
317
318
319
320 Discussion
321
322 The results show that abstract words are processed slower than concrete ones in both lexical
323 decision and recognition. This finding confirm the well-established concreteness effect (Paivio,
324 1986). As to emotional words, in the lexical decision task they yield more errors than abstract
325 concepts and in the recognition task they yield more errors than concrete concepts and slightly
326 more errors than abstract ones. This result suggests that emotional words cannot be properly
327 assimilated neither to other abstract words nor to concrete ones.
328 Across the two tasks, responses with the mouth were slower than those with the hand,
329 independently from the concept kind; this effect is not worth discussing since it was likely due to
330 the fact that the button to hold among the teeth was harder to press than the key to press with the
331 hand (see also Borghi and Zarcone, 2016).
332 As to the relationship of the different words with the hand and mouth effectors, we found no
333 difference in lexical decision task, suggesting that effectors are differently activated only in tasks
334 that require a deeper processing level. The interaction between Kind of concept and Effector was
335 however significant in the recognition task, in the analysis on accuracy. Both abstract and concrete
336 words yielded less errors with mouth than with hand responses, while emotional concepts yielded
337 significantly more errors with mouth than with hand responses. The results thus suggest that
338 abstract words are slightly facilitated with the mouth, as predicted. It is however unclear why this
339 facilitation occurred with concrete words too. The pattern of results of emotional words differed
340 from that of both concrete and abstract concepts – they elicited significantly more errors with
341 mouth than with hand responses.
342
343

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

390   dominant hand or in the mouth, between the teeth, and to respond to catch-trials by pressing it;
391   they were instead asked to press the pedal to respond to critical stimuli. The order of the blocks
392   was counterbalanced across participants. Participants were asked to press the pedal if they read an
393   Italian word, and to refrain from responding if the word they read was not an Italian one. They
394   were also required to respond to catch-trials by pressing the button with the hand or mouth,
395   depending on the condition. Hence the mouth and the hand were not the direct response effectors,
396   but they were occupied during the execution of the task.
397
398   *Recognition task*
399
400   The task was divided into two experimental blocks, each preceded by a training block of 8 trials
401   (3 words, 3 new words and 2 catch-trials). A set of 62 words was presented in each block,
402   composed by 24 critical words, 24 new words and 12 catch-trials. The order of the blocks was
403   counterbalanced across participants. Depending on the block, participants were required to keep
404   the button in their dominant hand or in the mouth, between the teeth. As to the critical stimuli,
405   participants were asked to press the pedal in case they recognized that the word on the screen had
406   already been presented in the previous task, or to refrain from responding if the read a new word.
407   When catch-trials were presented, they had to respond by pressing the button with the hand or
408   mouth, depending on the block.
409
410   **Results**
411
412   Two 3x2 ANOVAs on RTs and errors were performed for both tasks, one with participants and
413   one with materials as random factor, with factors *Type of Concept* (ABS; CNC; EMO) x *Effector*
414   (mouth; hand). For the participants analyses (indicated by F^1), condition means were obtained by
415   averaging across words, and for the items analyses (indicated by F^2) they were obtained by
416   averaging across participants.
417
418
419   *Lexical Decision*:
420
421   Overall response times were longer than those obtained in Experiment 1, likely due to the presence
422   of catch-trials. All erroneous trials (4,58%) were removed before the analysis of RTs. In the
423   analysis of response times, we found a significant main effect of the *Type of Concept* factor [F_1
424   (2,78) = 15.941; MS_e =214819.724; *p*< .001, n_P^2= .290];[F_2 (2,45) = 4.061; MS_e =174855.272;
425   *p*=.024, n_P^2= .153]. A T-Student test on paired samples on participants and on independent samples
426   on materials and the Effect Size (Cohen's *d*) showed that responses to abstract words were slower
427   than responses to both concrete [t_1(39)=4.175; SE= 7.55; p<.001; *d*= 0.2] [t_2(30)=1.803; SE=
428   16.908; p=.08; *d*= 0.6] and emotional words [t_1(39)=5.075; SE= 9.01; p<.001; *d*= 0.4]
429   [t_2(30)=2.592; SE= 16.669; p=.01; *d*=0.9] (see *Table 4*); (Mean ABS= 830.2 ms; Mean CNC=
430   798.7 ms; Mean EMO= 784.5 ms). We found no other significant results [F_s< 1.3], although the
431   trend of the Interaction between *Type of Concept x Effector* factors was in line with the hypothesis,
432   showing that responses to abstract words were slower than both those to concrete and emotional
433   ones, and that only abstract words had a slight advantage when the device was held in the mouth
434   than in the hand, while concrete words and especially emotional ones were faster when processed
435   with the device in the hand. Means are shown in *Table 2*.

436
437 In the analysis of the accuracy, the main effect of the *Effector* factor was significant [F_1 (1,39) =
438 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
439 that responses with the mouth were less accurate than those with the hand (Mean Mouth= 0.45;
440 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
441 other main effect or interaction was significant [F_s< .826]. Even if the main effect of *Type of*
442 *Concept* was not significant, the percentage of errors was higher with abstract than with emotional
443 and concrete words, in keeping with the results obtained with the RTs and with the well
444 documented concreteness effect (see *Table 3*).
445
446 *Recognition*:
447
448 All erroneous trials (35%) were removed before the analysis of RTs. In the analyses on response
449 times, we found a main effect of *Type of Concept* factor on participants [F_1 (2,78) = 3.37; MS_e=
450 574462.20; *p*=.033; n_P^2=.08] (Mean ABS= 889.11 ms; Mean CNC= 853.98 ms; Mean EMO=
451 874.10 ms), but not on materials [F_2 (2,45) = 1.7]. A t-test analysis on paired samples and Effect
452 size (Cohen's d) on participants showed that abstract words are significantly slower with respect
453 to concrete words [t(39)= 2.335; SE= 15.04; p=.02; *d*=0.3] (see *Table 4*). In the analysis on
454 materials the interaction between the factors *Type of Concept x Effector* resulted very close to
455 significance [F_2 (2,45) = 3.06; MS_e =306722.753; *p*=.05; n_P^2=.120]. No other significant main
456 effect or interaction were found [F_s<1.47].
457
458 In the analyses on accuracy, the predicted significant interaction between *Type of Concept* x
459 *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
460 =68.09; *p*=.019; n_P^2= .162]. A T-test analysis for paired samples and the effect sizes (Cohen's *d*)
461 showed that when participants responded to catch-trials with the mouth, abstract words yielded in
462 tendency more accurate responses than concrete words [t_1 (39)= -1.929; SE= .33; p=.06; *d*= 0.34],
463 while there was no difference with the hand [t_1(39)= -.261; SE= 0.14; p=.8; *d*= -0.03]. Responses
464 to abstract and emotional words did not differ when the mouth was occupied [t_1(39)= -1.29; SE=
465 0.23; p=.2; *d*= 0.17], while they differed when the hand was occupied [t_1(39)= -2.682; SE=0.27;
466 p=.01; *d*= 0.42], with emotional words producing more errors (Mean ABS-HAND= 2.6; Mean
467 EMO-HAND= 3.3). Moreover, responses to emotional and concrete words differed when given
468 with the hand, with emotional words producing significantly more errors [t_1(39)= -2.783; SE=
469 0.23; p=.008; *d*= 0.36] (see *Table 5*). A T-test analysis for independent samples on materials
470 revealed that there were no significant differences [F_s<1.13], although responses to emotional
471 words produced in tendency more errors when given with the hand than both abstract [t_2(30)=-
472 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
473 abstract and emotional words the recognition was facilitated with the mouth, for concrete ones
474 with the hand. (Mean ABS-M: 2.48; CNC-M:3.13; EMO-M: 2.78); (Mean ABS-H= 2.6; CNC-H=
475 2.68; EMO-H=3.3). Means of errors are shown in *Table 3* and *Figure 5*.
476
477 **Discussion**
478 As in Experiment 1, abstract words were processed slower than concrete ones in both lexical
479 decision and recognition tasks. Emotional words were faster than both concrete and abstract
480 concepts in the lexical decision task. Similarly to Experiment 1, our findings confirm the

481 concreteness effect and at the same time suggest that emotional words cannot be properly
482 assimilated neither to other abstract words nor to concrete ones.
483 As in Experiment 1, we did not find an interaction between Kind of Concept and Effector in the
484 lexical decision task. In the recognition task, instead, the interaction reached significance in the
485 analysis of accuracy. Abstract words yielded less errors in the mouth than in the hand condition,
486 while concrete words yielded less errors in the hand than in the mouth condition, as predicted by
487 the WAT (Words As social Tools) view. Interestingly, emotional words produced results similar
488 to those of abstract words, yielding less errors with the mouth than with the mouth.
489
490 **General discussion**
491
492 According to some proposals, abstract concepts evoke more linguistic experience than concrete
493 words (Borghi & Binkofski, 2014; Borghi et al., accepted; Dove, 2011; Gleitman et al., 2005). If
494 the involvement of language activates a motor simulation, this should result in a higher
495 engagement of the mouth effector during processing of abstract than of concrete words. The main
496 aim of this paper was to test the hypothesis that different kind of concepts, i.e. concrete, abstract
497 and emotional ones, differently engaged the mouth and hand effectors. The two experiments
498 implied engaging the mouth and the hand effectors either directly, to provide a response
499 (Experiment 1), or indirectly, keeping them occupied during the response (Experiment 2).
500
501 A further aim of this paper was related to the distinction between abstract, concrete and emotional
502 words. Since many authors consider emotional concepts as a subset of abstract concepts while
503 others tend to consider them as independent from both abstract and concrete ones, we intended to
504 verify whether performance with emotional words reflected that with abstract words or not.
505
506 Overall, our results confirmed the hypothesis that abstract words involve activation of the mouth,
507 but the effect was modulated by the task and differed depending on whether the response was
508 directly using that effector or not. In the following we will point out the main results, discussing
509 them in light of the advanced hypotheses. We will first illustrate results on the differences in
510 processing the three concept kinds independently of the effector, then we will focus on differences
511 between concepts kinds in relation to the activation of mouth and hand effectors.
512
513 **Overall processing differences between concept kinds.** The effect of *Type of concept* was
514 present in RTs analyses on both experiments and on both tasks: overall, abstract concepts were
515 processed slower than concrete ones (E1 and E2 lexical decision, E1 and E2 recognition) and in
516 Experiment 1 they yielded more errors than emotional concepts in the lexical decision task and
517 slightly more errors than concrete concepts in the recognition task. Our results confirm the well-
518 established concreteness effect (Paivio, 1986; but see exceptions to the effect when controlling
519 stimuli for valence: Kousta et al., 2011; Barca et al., 2002), that shows that abstract words are
520 slower than concrete ones, and extended it showing that in the lexical decision task they are also
521 slower than emotional words (see also Ponari et al., 2017).
522
523 As to emotional words, our results cast doubts on the assimilation of emotional to abstract
524 concepts: across experiments and tasks, the pattern of responses elicited by emotional words
525 differed from that of abstract words and occasionally from that of concrete words too. In the lexical
526 decision task of both experiments emotional words were processed faster than abstract words and

527   did not differ from concrete words. Our results are in line with those of a study by Siakaluk et al.
528   (2016) showing that valenced words were processed faster than other words in lexical decision
529   task. As to accuracy, in Experiment 1 responses to emotional concepts were also more accurate
530   than abstract words in lexical decision and less accurate than concrete ones in recognition. Overall,
531   emotional words differed in processing from both concrete and abstract concepts, confirming the
532   views according to which they represent a third kind of concept (Altarriba et al., 1999; Setti and
533   Caramelli, 2005).
534

535   **Processing differences between concept kinds in relation to the effectors.**
536   The experiments we designed were driven from the hypothesis that abstract concepts would
537   activate more the mouth motor system. Furthermore, we wanted to explore whether the two
538   effectors, mouth and hand, would be differently activated with emotional words. We thus expected
539   to find a *Type of Concept x Effector* interaction.
540

541   If we consider lexical decision, in neither experiment the predicted Type of Effector x Concept
542   interaction was significant. Results thus seemed to suggest that the lexical decision task did not
543   lead to a differential activation of the hand and mouth effectors, likely because of the superficial
544   processing level it implied.
545

546   The results consistently differed if we consider the Recognition task. The interaction was not
547   significant in RTs, but it reached significance in accuracy in both experiments. Notice that,
548   differently than in the lexical decision task, in recognition tasks accuracy is a more important
549   measure compared to RTs also because of the high percentage of recognition errors. In Experiment
550   1, in which hand and mouth were the direct response effectors, abstract concepts were slightly
551   facilitated with the mouth, as predicted. It was however unclear why this facilitation occurred with
552   concrete words too. In Experiment 2, in which the hand and mouth were occupied but responses
553   were provided in the same manner, pressing a pedal with the foot, responses to abstract words
554   were the most accurate ones in the mouth condition; they were significantly more accurate than
555   responses to concrete words, while in the hand condition the accuracy of abstract and concrete
556   words did not differ. These results clearly confirm our hypothesis, indicating that abstract words
557   were facilitated when the mouth was activated, and extend previous results, showing that such a
558   facilitation occurred not only when the mouth was the direct response effector but also when the
559   mouth was occupied with a device.
560

561   This confirms the predictions of the WAT proposal, according to which abstract concepts re-enact
562   linguistic and social experience more than concrete concepts, hence determining a higher
563   activation of the mouth. Three possible mechanisms can underline this activation (see for further
564   discussion Borghi & Zarcone, 2016; Borghi et al., accepted): a. the re-enactment of the acquisition
565   experience, which is mainly linguistic and occurs in a social context; b. the inner speech used to
566   re-explain to us the meaning of abstract concepts; c. the meta-cognitive awareness that our
567   conceptual knowledge is inadequate followed by the motor preparation to ask to others information
568   on words meaning (social-metacognition, Borghi et al., accepted). The present study does not
569   allow us to determine which of the three mechanisms is responsible of the effects; further research
570   is needed in order to disentangle them.
571

572   The pattern of emotional concepts was, instead, more fluctuating across the two experiments. In
573   the recognition task of Experiment 1 emotional words had a disadvantage in the mouth condition,
574   differently from abstract words. Conversely, in the same task of Experiment 2, emotional words
575   showed a disadvantage in the hand condition, producing less errors with the mouth. One could
576   argue that the effect is due to interference with emotional concepts when the effector of response
577   is the mouth, and to facilitation when it is not. We do not favor this interpretation, though, for a
578   couple of reasons. First, the result of Experiment 2 reveal that the difference between emotional
579   concepts and the other concepts concerns the hand responses, not the mouth ones, rendering the
580   hypothesis of a facilitation with the mouth really unlikely. Second, previous results with abstract
581   not emotional concepts showed that responding with the mouth provoked a facilitation, not an
582   interference (Borghi & Zarcone, 2016). Finally, the variable pattern of activation of the hand and
583   mouth effectors with emotional words is in keeping with recent experimental results. Ratings
584   results showed that emotional concepts activate both the mouth and the hand effectors, while
585   mental states concepts activate more selectively the mouth (Ghio et al., 2013), andfMRI results
586   clearly demonstrated that while the face/mouth motor system in the brain is more activated by
587   more pure abstract concepts as mental state concepts than by emotional ones, which activate hand
588   and face motor cortex to similar degrees (Dreyer and Pulvermuller, 2017). Overall, this finding is
589   in line with views according to which emotions represent a third kind of concepts, structurally
590   different from both concrete and abstract ones (see Barca et al., 2017, and Mazzuca et al., 2017,
591   for further discussion), and with the proposal according to which emotional concepts, being more
592   grounded than other abstract concepts, provide a bootstrapping mechanism to learn them (Ponari
593   et al., 2017).
594
595   While we found that abstract concepts processing was facilitated with the mouth, the results are
596   less marked than in a previous study (Borghi and Zarcone, 2016). We ascribe this difference to
597   two factors: first, to the fact that in the previous study participants were provided with a context
598   and not only with single words, and second, to the fact that the task was a deep processing one.
599
600   The present study adds important information to previous studies on concepts and effector
601   activation: it suggests that the mouth and hand effectors can be differently activated depending on
602   the task and on the depth level it implies. The different effectors did not influence results in the
603   lexical decision task, but they had an impact on a subsequent recognition task.
604
605   **Conclusion**
606
607   Overall, our studies show that, in general, abstract words are more difficult to process, as revealed
608   by the slower RTs, independently from the task. This confirms the concreteness effect, well-
609   established in the literature. Across the tasks and experiments, emotional concepts had instead a
610   fluctuating pattern. This suggests that they are markedly different from both concrete and abstract
611   concepts.
612   If we consider the relationship between concepts and effectors, we confirmed the hypothesis
613   proposed by the WAT proposal that abstract concepts had an advantage in the mouth condition.
614   The result was however modulated by the task: the effectors did not have a different effect on
615   concepts in a lexical decision task, but impacted a subsequent recognition task. Overall, our
616   findings highlight that concepts are grounded and activate bodily experiences, but they also point
617   out the exquisitely flexible character of our conceptual representation.

618
619
620 **References**
621
622 Altarriba, J., Bauer, L. M., & Benvenuto, C. (1999). Concreteness, context availability, and
623 imageability ratings and word associations for abstract, concrete, and emotion words. *Behavior*
624 *Research Methods, Instruments, & Computers, 31*(4), 578-602.
625
626 Altarriba, J., Bauer, L.M. (2004).The distinctiveness of emotion concepts: a comparison between
627 emotion, abstract, and concrete words. *American Journal of Psychology, 117*(3), 389–410. doi:
628 10.2307/4149007.
629
630 Barca, L., Burani, C., & Arduino, L. S. (2002). Word naming times and psycholinguistic norms
631 for Italian nouns. *Behavior Research Methods, Instruments, & Computers*, *34*(3), 424-434.
632
633 Barca, L., Mazzuca, C., Borghi, A.M. (2017). Pacifier use and conceptual relations of abstract
634 and emotional concepts. *Front. Psychol*. 8:2014. doi: 10.3389/fpsyg.2017.02014.
635
636 Barsalou, L. W. (2003). Abstraction in perceptual symbol systems. *Philosophical Transactions*
637 *of the Royal Society B: Biological Sciences*, *358*(1435), 1177-1187.
638
639 Barsalou, L. W. (2008). Grounded cognition. *Annu. Rev. Psychol.*, *59*, 617-645.
640
641 Barsalou, L. W. (2010). Grounded cognition: Past, present, and future. *Topics in cognitive*
642 *science*, *2*(4), 716-724.
643
644 Barsalou, L.W. (2016). On staying grounded and avoiding quixotic dead ends. *Psychonomic*
645 *Bulletin & Review, 23*, 1–21.
646
647 Borghi, A.M., Caruana, F. (2015). Embodiment Theory. In: James D. Wright (editor-in-chief),
648 *International Encyclopedia of the Social & Behavioral Sciences*,2nd edition, Vol 7. Oxford:
649 Elsevier. pp. 420-426. ISBN: 978008097086.
650
651 Borghi, A. M., Flumini, A., Cimatti, F., Marocco, D., & Scorolli, C. (2011). Manipulating
652 objects and telling words: a study on concrete and abstract words acquisition. *Frontiers in*
653 *psychology*, *2*, 15.
654
655 Borghi, A. M., & Binkofski, F. (2014). *Words As social Tools: An embodied view on abstract*
656 *concepts*. New York: Springer.
657
658 Borghi, A. M., Binkofski, F., Castelfranchi, C., Cimatti, F., Scorolli, C., & Tummolini, L.
659 (2017). The challenge of abstract concepts. *Psychological Bulletin*, *143*(3), 263.
660
661 Borghi, A. M., & Cimatti, F. (2009, January). Words as tools and the problem of abstract word
662 meanings. In *Proceedings of the Annual Meeting of the Cognitive Science Society* (Vol. 31, No.
663 31).

664
665 Borghi, A.M., Barca, L., Binkofski, F., Tummolini, L. (accepted). Abstract concepts, language
666 and sociality: from acquisition to inner speech. *Philosophical Transactions of the Royal Society*
667 *B: Biological Sciences*.
668
669 Borghi, A. M., & Zarcone, E. (2016). Grounding abstractness: abstract concepts and the
670 activation of the mouth. *Frontiers in psychology*, *7*, 1498.
671
672 Buccino, G., Riggio, L., Melli, G., Binkofski, F., Gallese, V., & Rizzolatti, G. (2005). Listening
673 to action-related sentences modulates the activity of the motor system: A combined TMS and
674 behavioral study. *Cognitive Brain Research*, *24*(3), 355-363.
675
676 Cappa, S. F., & Pulvermüller, F. (2012). Cortex special issue: Language and the motor
677 system. *Cortex*, *48*(7), 785-787.
678
679 Clark, A. (1998). Magic words: How language augments human computation. Language and
680 thought: Interdisciplinary themes, 162–183.
681
682 Connell, L., Lynott, D., & Carney, J. (2017). Interoception: The Forgotten Modality in
683 Perceptual Grounding of Concepts. *Proceedings of Cognitive Science Society*.
684
685 Connell, L., Lynott, D., & Banks, B. (accepted). Interoception: The forgotten modality in
686 perceptual
687 grounding of abstract and concrete concepts. *Philosophical Transactions of the Royal Society B:*
688 *Biological Sciences*.
689
690 Crutch, S. J., Troche, J., Reilly, J., & Ridgway, G. R. (2013). Abstract conceptual feature
691 ratings: the role of emotion, magnitude, and other cognitive domains in the organization of
692 abstract conceptual knowledge. *Frontiers in human neuroscience*, *7*.
693
694 Cuccio, V., & Gallese, V. (accepted). A Peircean account of concepts.
695 Grounding abstraction in phylogeny through a comparative neuroscientific perspective.
696 *Philosophical Transactions of the Royal Society B: Biological Sciences*.
697
698 Della Rosa, P. A., Catricalà, E., Vigliocco, G., & Cappa, S. F. (2010). Beyond the abstract—
699 concrete dichotomy: Mode of acquisition, concreteness, imageability, familiarity, age of
700 acquisition, context availability, and abstractness norms for a set of 417 Italian words. *Behavior*
701 *research methods, 42*(4), 1042-1048.
702
703 Dove, G. (2009). Beyond Perceptual symbols: a call for representational pluralism. *Cognition*,
704 110, 412-31.
705
706 Dove, G. (2011). On the need for embodied and disembodied cognition. *Frontiers in*
707 *Psychology*, 1, 242.
708

709   Dove, G. (2014). Thinking in words: language as an embodied medium of thought. *Topics in*
710   *cognitive science, 6*(3), 371-389.
711
712   Dove, G. (2015). How to go beyond the body: an introduction. *Frontiers in psychology*, *6*, 660.
713
714   Dove, G. (accepted). Language as a Disruptive Technology: Abstract Concepts, Embodiment,
715   and the Flexible Mind. *Philosophical Transactions of the Royal Society B: Biological Sciences.*
716
717   Dreyer, F. R., Frey, D., Arana, S., von Saldern, S., Picht, T., Vajkoczy, P., & Pulvermüller, F.
718   (2015). Is the motor system necessary for processing action and abstract emotion words?
719   Evidence from focal brain lesions. *Frontiers in Psychology*, *6*.
720
721   Dreyer, F. R., & Pulvermüller, F. (2017). Abstract semantics in the motor system?–An event
722   related fMRI study on passive reading of semantic word categories carrying abstract
723   emotional and mental meaning. *Cortex*.
724
725   Ghio, M., Vaghi, M. M. S., & Tettamanti, M. (2013). Fine-Grained Semantic Categorization
726   across the Abstract and Concrete Domains. *PLoS ONE*, *8*(6).
727   https://doi.org/10.1371/journal.pone.0067090
728
729   Gleitman, L. R., Cassidy, K., Nappa, R., Papafragou, A., & Trueswell, J. C. (2005). Hard
730   words. *Language Learning and Development, 1*(1), 23-64.
731
732   Glenberg, A. M. (2015). Few believe the world is flat: How embodiment is changing the
733   scientific understanding of cognition. *Canadian Journal of Experimental Psychology/Revue*
734   *canadienne de psychologie expérimentale*, *69*(2), 165.
735
736   Glenberg, A. M., & Gallese, V. (2012). Action-based language: A theory of language
737   acquisition, comprehension, and production. *cortex*, *48*(7), 905-922.
738
739   Glenberg, A. M., Witt, J. K., & Metcalfe, J. (2013). From the revolution to embodiment: 25
740   years of cognitive psychology. *Perspectives on Psychological Science*, *8*(5), 573-585.
741
742   Granito, C., Scorolli, C., & Borghi, A. M. (2015). Naming a Lego World. The Role of Language
743   in the Acquisition of Abstract Concepts. *PloSone, 10*(1), e0114615.
744
745   Hauk, O., Johnsrude, I., & Pulvermüller, F. (2004). Somatotopic representation of action words
746   in human motor and premotor cortex. *Neuron*, *41*(2), 301-307.
747
748   Kousta, S. T., Vigliocco, G., Vinson, D. P., Andrews, M., & Del Campo, E. (2011). The
749   representation of abstract words: why emotion matters. *Journal of Experimental Psychology:*
750   *General*, *140*(1), 14.
751
752   Lupyan, G., & Clark, A. (2015). Words and the World Predictive Coding and the Language-
753   Perception-Cognition Interface. *Current Directions in Psychological Science, 24*(4), 279-284.
754

755 Mazzuca, C., Barca, L., & Borghi, A. M. (2017). The Peculiarity of Emotional Words: A
756 Grounded Approach. *Rivista internazionale di Filosofia e Psicologia*, *8*(2), 124-133.
757
758 Mellem, M. S., Jasmin, K. M., Peng, C., & Martin, A. (2016). Sentence processing in anterior
759 superior temporal cortex shows a social-emotional bias. *Neuropsychologia*, *89*, 217-224.
760
761 Newcombe, P. I., Campbell, C., Siakaluk, P. D., & Pexman, P. M. (2012). Effects of
762 emotional and sensorimotor knowledge in semantic processing of concrete and abstract
763 nouns. *Frontiers in human neuroscience*, *6*.
764
765 Oldfield, R. C. (1971). The assessment and analysis of handedness: the Edinburgh
766 inventory. *Neuropsychologia*, *9*(1), 97-113.
767
768 Paivio, A. (1986). *Mental Representations: A Dual Coding Approach*. Oxford, UK: Oxford
769 University Press.
770
771 Pecher, D., Boot, I., van Dantzig, S. (2011). Abstract concepts: sensory motor grounding,
772 metaphors, and beyond. In B. Ross (Ed.), *The Psychology of Learning and Motivation*, Vol. 54,
773 217-48. Burlington: Academic Press.
774
775 Ponari, M., Norbury, C. F., & Vigliocco, G. (2017). Acquisition of abstract concepts is
776 influenced by emotional valence. *Developmental Science*.
777
778 Prinz, J. J. (2012). Beyond human nature. How culture and experience shape our
779 lives.London; New York, NY: Penguin.
780
781 Pulvermüller, F. (2005). Brain mechanisms linking language and action. *Nature Reviews*
782 *Neuroscience*, *6*(7), 576.
783
784 Recchia, G., & Jones, M. N. (2012). The semantic richness of abstract concepts. *Frontiers in*
785 *human neuroscience, 6.*
786
787 Roversi, C., Borghi, A. M., & Tummolini, L. (2013). A marriage is an artefact and not a walk
788 that
789 we take together: An experimental study on the categorization of artefacts. *Review of*
790 *Philosophy and Psychology, 4*(3), 527–542.
791
792 Setti, A., Caramelli, N. (2005) Different domains in abstract concepts. In B. Bara, B.
793 Barsalou, M. Bucciarelli (Eds.). *Proceedings of the XXVII Annual Conference of the*
794 *Cognitive Science*. Mahwah NJ: Erlbaum.
795
796 Siakaluk, P. D., Newcombe, P. I., Duffels, B., Li, E., Sidhu, D. M., Yap, M. J., & Pexman, P. M.
797 (2016). Effects of Emotional Experience in Lexical Decision. *Frontiers in psychology, 7*, 1157.
798
799 Thill, S., & Twomey, K. E. (2016). What's on the inside counts: A grounded account of concept
800 acquisition and development. *Frontiers in psychology, 7*.

801   Tomasino, B., & Rumiati, R. I. (2013). Introducing the special topic "The when and why of
802   sensorimotor processes in conceptual knowledge and abstract concepts". *Frontiers in human*
803   *neuroscience*, 7.
804
805   Topolinski, S., & Strack, F. (2009). Motormouth: mere exposure depends on stimulus-specific
806   motor simulations. *Journal of Experimental Psychology: Learning, Memory, and Cognition*,
807   *35*(2), 423.
808
809   Topolinski, S., Maschmann, I. T., Pecher, D., & Winkielman, P. (2014). Oral approach–
810   avoidance: Affective consequences of muscular articulation dynamics. *Journal of personality*
811   *and social psychology*, *106*(6), 885.
812
813   Wang, X., Wu, W., Ling, Z., Xu, Y., Fang, Y., Wang, X., ... & Bi, Y. (2017). Organizational
814   Principles of Abstract Words in the Human Brain. *Cerebral Cortex*, 1-14.
815
816   Wauters, L. N., Tellings, A. E., Van Bon, W. H., & Van Haaften, A. W. (2003). Mode of
817   acquisition of word meanings: The viability of a theoretical construct. *Applied*
818   *Psycholinguistics, 24*(03), 385-406.

Figure 1

Pedal used to respond to the stimuli (Experiment 2).

Figure 2

Button used to respond to the stimuli with both the effectors (Experiment 1), and catchtrial (Experiment 2).

Figure 3

General procedure of lexical decision and recognition task (Experiment 1 and 2).
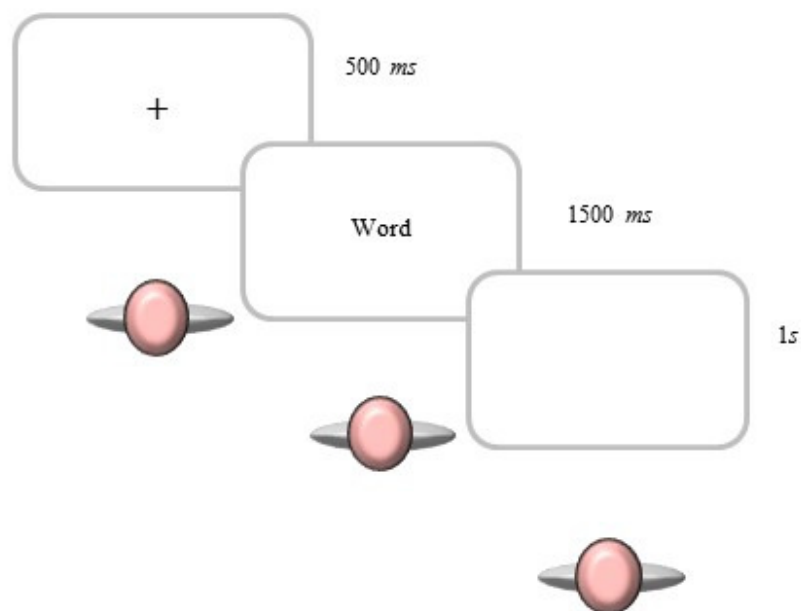
500 *ms*

+

Word

1500 *ms*

1*s*

Figure 4(on next page)

Interaction between *Type of Concept* and *Effector* factors in accuracy, Experiment 1.

Figure 5(on next page)

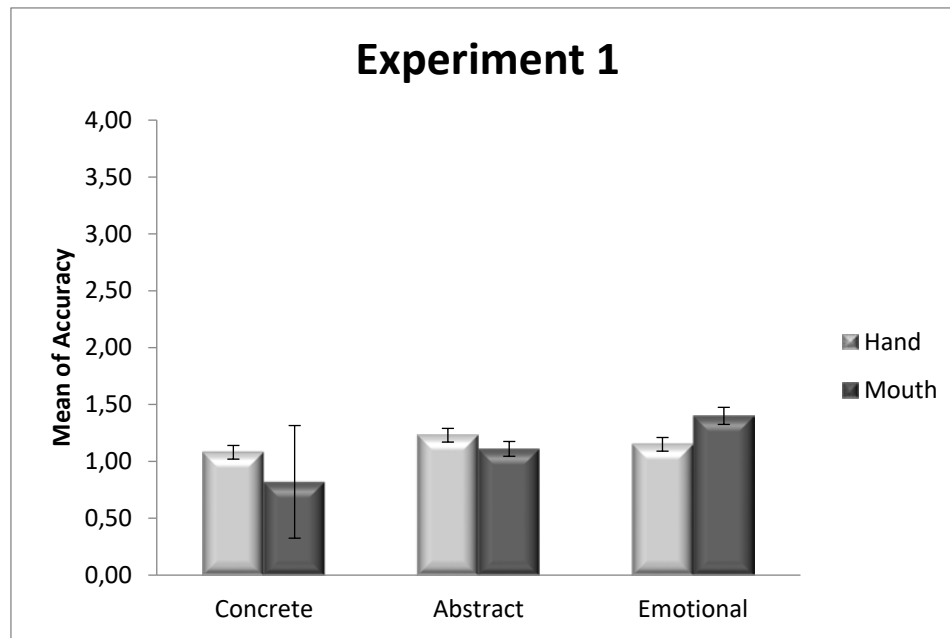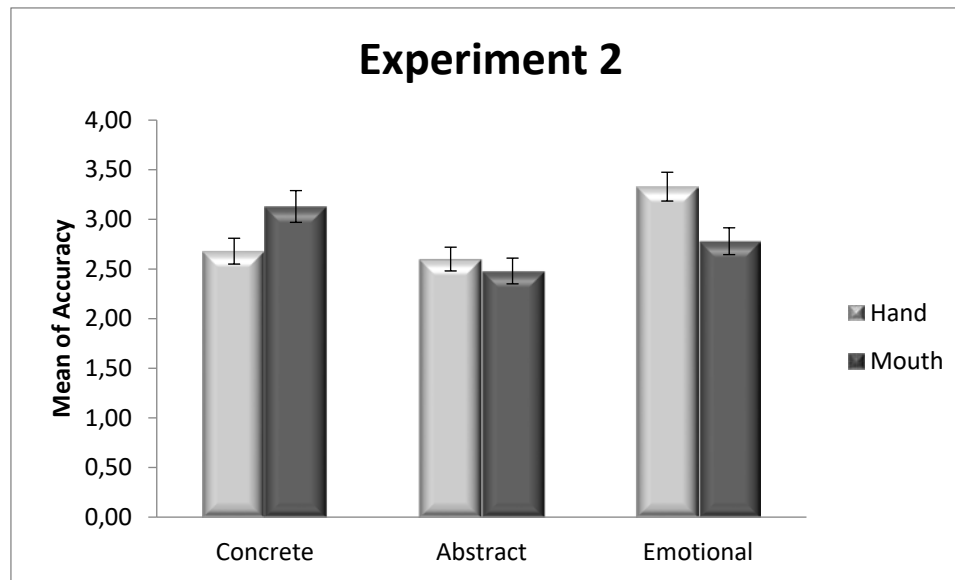Interaction between *Type of Concept* and *Effector* factors in accuracy, Experiment 2.

Experiment 2

Table 1(on next page)

Selected stimuli from Della Rosa et al.,2010 database.

ITALIAN WORD	ENGLISH WORD	FREQUENCY	NUMBER OF LETTERS	FREQUENCY MEAN	LETTERS MEAN
Affermazione	Affirmation	59	12		
Analogia	Analogy	8	8		
Circostanza	Circumstance	70	11		
Concetto	Concept	118	8		
Fascino	Appeal	149	7		
Funzione	Function	185	8		
Indiscrezione	Indiscretion	16	13		
Inefficienza	Inefficiency	17	12		
Inesperienza	Inexperience	5	12		
Insufficienza	Insufficiency	15	13		
Logica	Logic	107	6		
Merito	Merit	141	6		
Ozio	Idleness	9	4		
Reputazione	Reputation	27	11		
Tendenza	Tendency	161	8		
Unanimità	Unanimity	37	8	*Abstract*=70.25	9.19
Alghe	Seaweed	24	5		
Alveare	Beehive	11	7		
Canoa	Canoe	25	5		
Circo	Circus	43	5		
Cravatta	Tie	38	8		
Elefante	Elephant	36	8		
Falce	Sickle	5	5		
Flotta	Fleet	35	6		
Gallo	Cock	12	5		
Giraffa	Giraffe	1	7		
Minerale	Mineral	9	8		
Oca	Goose	29	3		
Palude	Swamp	12	6		
Telegrafo	Telegraph	3	9		
Torre	Tower	44	5		
Trattore	Tractor	2	8	*Concrete*=20.56	6.25
Abbandono	Abandonment	91	9		
Agitazione	Agitation	25	10		
Agonia	Agony	29	6		
Conflitto	Conflict	140	9		
Disperazione	Desperation	101	12		
Emergenza	Emergency	161	9		
Fallimento	Failure	99	10		
Fremito	Trembling	11	7		
Giuramento	Vow	13	10		
Impulso	Impulse	50	7		
Ira	Anger	45	3		
Orrore	Horror	77	6		
Pericolo	Danger	250	8		
Stupore	Wonder	62	7		
Terrore	Terror	96	7		
Tradimento	Betrayal	73	10	*Emotional*=82.69	8.13

1

Table 2(on next page)

Means of RTs for both tasks, Experiment 1 and 2.

RTs of Lexical Decision Task 1,2

		Experiment 1				Experiment 2			
Effector	Type of Concepts	M (RT_p)	SD_p	M (RT_m)	SD_m	M (RT_p)	SD_p	M (RT_m)	SD_m
Mouth	Abstract	741.82 *ms*	132.146	759.68 *ms*	116.27	828.80 *ms*	130.93	813.66 *ms*	53.63
	Concrete	703.19 *ms*	105.58	701.87 *ms*	59.74	801.14 *ms*	114.04	791.94 *ms*	57.58
	Emotional	703.02 *ms*	113.62	706.38 *ms*	68.11	796.93 *ms*	127.12	786.35 *ms*	46.40
Hand	Abstract	689.21 *ms*	106.93	702.09 *ms*	108.01	831.77 *ms*	122.23	827.51 *ms*	81.99
	Concrete	640.38 *ms*	104.97	642.76 *ms*	69.53	796.36 *ms*	112.27	788.25 *ms*	41.63
	Emotional	641.62 *ms*	98.38	642.98 *ms*	66.22	772.09 *ms*	102.20	768.40 *ms*	49.23

RTs of Recognition Task 1,2

		Experiment 1				Experiment 2			
Mouth	Abstract	784.5 *ms*	130.77	773.12 *ms*	47.58	883.81 *ms*	95.56	877.15 *ms*	45.04
	Concrete	727.8 *ms*	86.38	732.90 *ms*	75.60	856.84 *ms*	173.72	864.37 *ms*	52.26
	Emotional	773 *ms*	102.23	768.09 *ms*	58.13	898.94 *ms*	103.87	901.65 *ms*	65.32
	Abstract	752 *ms*	134.83	754.51 *ms*	75.02	894.41 *ms*	115.17	897.26 *ms*	87.67

| Hand | Concrete | 684.3 *ms* | 110.79 | 682.99 *ms* | 70.97 | 851.12 *ms* | 121.01 | 847.08 *ms* | 34.86 |
| | Emotional | 707 *ms* | 128.14 | 703.78 *ms* | 49.42 | 849.27 *ms* | 116.45 | 849.49 *ms* | 76.68 |

1

Table 3(on next page)

Means of Accuracy for both tasks, Experiment 1 and 2.

Accuracy of Lexical Decision Task 1,2

Effector	Type of Concepts	Experiment 1				Experiment 2			
		M (err_p)	SD_p	M (err_m)	SD_m	M (err_p)	SD_p	M (err_m)	SD_m
Mouth	Abstract	0.32	0.65	0.81	1.22	0.52	0.75	1.31	1.66
	Concrete	0.25	0.58	0.62	0.88	0.45	0.81	1.13	0.80
	Emotional	0.15	0.36	0.37	1.02	0.37	0.58	0.94	0.92
Hand	Abstract	0.37	0.62	0.93	1.56	0.35	0.53	0.88	1.4
	Concrete	0.2	0.72	0.5	0.89	0.20	0.46	0.50	0.73
	Emotional	0.12	0.51	0.31	0.6	0.30	0.60	0.75	1.73

Accuracy of Recognition Task 1,2

		Experiment 1				Experiment 2			
Mouth	Abstract	1.11	0.88	5.56	2.92	2.48	1.67	3.09	1.65
	Concrete	0.82	0.62	4.13	2.62	3.13	2.06	3.84	1.59
	Emotional	1.4	0.97	7	3.26	2.78	1.76	3.40	1.25
	Abstract	1.23	0.79	6.19	3.92	2.6	1.56	3.25	1.22

| Hand | Concrete | 1.08 | 0.81 | 5.44 | 2.65 | 2.6 | 1.67 | 3.31 | 1.06 |
| | Emotional | 1.15 | 0.79 | 5.79 | 3.23 | 3.3 | 1.88 | 4.15 | 1.42 |

1

Table 4 (on next page)

T student tests on *Type of Concept* factor for both tasks and Experiments (1 and 2).

Task	Abstract vs Emotional words		
Lexical Decision 1, RTs	(Paired samples)	Participants	$t_{(39)}= 6.239$; SE=6.92; p<.001; $d= 0.42$
	(Independent samples)	Materials	$t_{(30)}= 2.027$; SE=27.72; p=.05; $d=0.7$
Lexical Decision 2, RTs	(Paired samples)	Participants	$t_{(39)}=5.075$; SE= 9.01; p<.001; $d= 0.4$
	(Independent samples)	Materials	$t_{(30)}=2.592$; SE= 16.669; p=.01; $d=0.9$
Lexical Decision 1, Accuracy	(Paired samples)	Participants	$t_{(39)}= 2.379$; SE=0.08; p=.02; $d= 0.4$
	(Independent samples)	Materials	*n.s.*
Recognition 1, RTs	(Paired samples)	Participants	$t_{(39)}=2.495$; SE=11.3; p=.01; $d=0.2$
	(Independent samples)	Concepts	*n.s.*
Recognition 2, Accuracy	(Paired samples)	Participants	$t_{(39)}= -2.652$; SE= .19; p=.01; $d=0.3$

	(Independent samples)	Concepts	n.s.
	Abstract vs Concrete words		
Lexical Decision 1, RTs	(Paired samples)	Participants	$t_{(39)}$= 6.375; SE= 6.85; p<.001; d= 0.43
	(Independent samples)	Materials	$t_{(30)}$=2.130; SE=27.49; p=.04; d=0.7
Lexical Decision 2, RTs	(Paired samples)	Participants	$t_{(39)}$=4.175; SE= 7.55; p<.001; d= 0.2
	(Independent samples)	Materials	$t_{(30)}$=1.803; SE= 16.908; p=.08; d= 0.6
Lexical Decision 1, Accuracy	(Paired samples)	Participants	$t_{(39)}$= 1.280; SE= 0.09; p=.2; d=0.2
	(Independent samples)	Materials	n.s.
Recognition 1, RTs	(Paired samples)	Participants	$t_{(39)}$ 2.681; SE= 10.9; p<.001; d=0.6
	(Independent samples)	Materials	$t_{(30)}$=2.640; SE=21.1; p=.01; d=0.9

Recognition 2, RTs	(Paired samples)	Participants	$t_{(39)}$= 2.335; SE= 15.04; p=.02; d=0.3
	(Independent samples)	Materials	*n.s.*
Recognition 1, Accuracy	(Paired samples)	Participants	$t_{(39)}$= 1.749; SE=0.12; p=.08; d= 0.3
	(Independent samples)	Materials	*n.s.*
	Concrete vs Emotional words		
Recognition 1, RTs	(Paired samples)	Participants	$t_{(39)}$= -3.411; SE= 9.96; p=.002; d=0.3
	(Independent samples)	Materials	*n.s.*
Recognition 1, Accuracy	(Paired samples)	Participants	$t(39)$= -2.353; SE=0.13; p=.02; d=0.4
	(Independent samples)	Materials	*n.s.*

1

Table 5(on next page)

T student tests on Interactions between *Type of Concept* and *Effector* factors on accuracy of recognition task, Experiment 1 and 2 .

	Experiment 1	
	Abstract vs Emotional words	
Participants *(Paired samples)*	Mouth	$t_{(39)}$=-2.05; SE= 0.13; p=.04; *d*=0.3
Materials *(Independent samples)*	Mouth	*n.s.*
Participants *(Paired samples)*	Hand	*n.s.*
Materials *(Independent samples)*	Hand	*n.s.*
	Concrete vs Emotional words	
Participants *(Paired samples)*	Mouth	$t_{(39)}$=-3.14; SE= 0.18; p=.003; *d*=0.6
Materials *(Independent samples)*	Mouth	$t_{(30)}$=-2.743; SE=1.04; p=.01; d=0.9
Participants *(Paired samples)*	Hand	*n.s.*
Materials *(Independent samples)*	Hand	*n.s.*
	Abstract hand vs. Concrete mouth	

Participants *(Paired samples)*		$t_{(39)}$=2.594; SE=0.15; p=.01; d=0.5
Materials *(Independent samples)*		*n.s.*

Emotional hand vs. Concrete mouth

Participants *(Paired samples)*		$t_{(39)}$= -2.209; SE= 0.14; p=.03; d=0.4
Materials *(Independent samples)*		*n.s.*

Experiment 2

Abstract vs Emotional words

Participants *(Paired samples)*	Mouth	$t_{(39)}$= -1.29; SE= 0.23; p=.2; d= 0.17
Materials *(Independent samples)*	Mouth	*n.s.*
Participants *(Paired samples)*	Hand	$t_{(39)}$= -2.682; SE=0.27; p=.01; d= 0.42

Materials *(Independent samples)*	Hand	$t_{(30)}$=-1.931; SE=.30; p=.06; d=0.7
Concrete vs Emotional words		
Participants *(Paired samples)*	Mouth	*n.s.*
Materials *(Independent samples)*	Mouth	*n.s.*
Participants *(Paired samples)*	Hand	$t_{(39)}$= -2.783; SE=0.23; p=.008; *d*= 0.36
Materials *(Independent samples)*	Hand	$t_{(30)}$=-1.901; SE=.26; p=.06; *d*=0.8
Abstract vs Concrete words		
Participants *(Paired samples)*	Mouth	$t_{(39)}$= -1.929; SE= .33; p=.06; *d*= 0.34
Materials *(Independent samples)*	Mouth	*n.s.*
Participants *(Paired samples)*	Hand	$t_{(39)}$= .261; SE= 0.14; p=.8; *d*= -0.03
Materials *(Independent samples)*	Hand	*n.s.*

1