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Size coding of alternative responses is sufficient to induce a potentiation effect with manipulable objects

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1 **SIZE CODING OF ALTERNATIVE RESPONSES IS SUFFICIENT TO INDUCE A**
2 **POTENTIATION EFFECT WITH MANIPULABLE OBJECTS**

3

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11

12 **Abstract: 329 words**

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17 **Appendices: 1**

18 **Footnotes: 3**

1 **Abstract**

2 The mere perception of manipulable objects usually grasped with a power-grip (e.g., an apple)
3 or a precision-grip (e.g., a cherry) potentiate power-grip- and precision-grip-responses,
4 respectively. This effect is seen as to be driven by automatic access of the representation of
5 manipulable objects that includes a motor representation of usually performed grasping
6 behaviors (i.e., the embodied view). Nevertheless, a competing account argues that this effect
7 could be due to an overlapping of size codes used to represent both manipulable objects and
8 response options. Indeed, objects usually grasped with a power- and a precision-grip (e.g., an
9 apple vs. a cherry) could be coded as large- and small-objects, respectively; and power- and
10 precision-grip responses as large- and small-responses, respectively. We conducted 4
11 experiments to test this hypothesis. In Experiment 1, the response device usually used in
12 studies reporting a potentiation effect is fixed horizontally (the grasping component of
13 responses was removed). We instructed participants to press the small-switch with their
14 index-digit and the large-switch with their palm-hand. In line with the size-coding-hypothesis,
15 responses on the small-switch performed with the index-digit led to shorter RTs when objects
16 usually associated with a precision-grip (e.g., a cherry) were presented compared to objects
17 usually associated with a power-grip (e.g., an apple). A reverse pattern was obtained for
18 responses on the large-switch performed with the palm-hand. In Experiments 2, 3 and 4, we
19 went further by investigating which factors of Experiment 1 allow the size coding of
20 responses: the size of switch and/or the size of the effector part used. Data confirmed the
21 critical involvement of the size of switches and the possible involvement of the size of the
22 effector part used. Thus, data support the possibility that the potentiation of grasping is due to
23 a compatibility/incompatibility between size codes rather than involving motor
24 representations of usually performed grasping behaviors as advocated in several embodied
25 views. Moreover, data support the possibility that responses are coded thanks to a size code
26 that extends the Theory of Event Coding.

27 **Keywords**

28 Motor representations; Embodied Cognition; Potentiation Effect; Size; Manipulable Objects;
29 Stimulus-Response Compatibility

30

31 **Supplementary material**

32 The raw data, the analyses performed, and the stimuli used can be found at osf.io/c6tva.

33

34 **Highlights**

- 35 • Large and small manipulable objects can potentiate large and small responses, respectively
- 36 • The size coding of responses can depend on the switch size and the effector size
- 37 • The size is a relevant dimension to code responses options
- 38 • The usual potentiation of power- and precision-grip could be due to a size coding of
- 39 responses

40 **1. Introduction**

41 Understanding how visual and motor processes are linked is of a primary interest in
42 cognitive sciences. Researchers have often used potentiation effects induced by objects to
43 investigate this link. The possibility that the mere perception of manipulable objects
44 automatically potentiate compatible manual behaviors was first reported by Tucker and Ellis
45 (1998). They observed that manipulable objects with a handle oriented toward the left or right
46 (e.g., a fork) facilitate a manual response located in the same side. It is usually argued that
47 manipulable objects allow an automatic access to an object representation that includes motor
48 components resulting in a covert motor preparation. Such a view is especially assumed by
49 proponents of various embodied views of object representation (Barsalou, 2008; Borghi &
50 Riggio, 2015; see Matheson, White & McCullen, 2015 for a review). Nevertheless, other
51 authors have questioned this interpretation and have developed an alternative explanation
52 (Anderson, Yamagishi & Karavia, 2002; Matheson, White & McCullen, 2014; Phillips &
53 Ward, 2002; Roest, Pecher, Naeije & Zeelenberg, 2016; see Proctor & Miles, 2014 for a
54 review). They particularly argue that some features of manipulable objects (e.g., the object
55 handle) automatically grabs attention to a specific side of the object. This lateralized attention
56 would potentiate in turn actions on the same side as in the more classical Simon effect
57 (Simon, 1969). This hypothesis is supported by various researches that showed the
58 potentiation effect of lateralized responses while stimuli presented were no longer
59 manipulable objects (e.g., animals with their head turned toward the left or right; Matheson et
60 al., 2014; Pellicano, Iani, et al., 2018; Pellicano, Luigi, et al., 2018; Xiong, Proctor &
61 Zelaznik, 2019).

62 Although the embodied explanation is undermined by these data, there is another well-
63 established and well-replicated potentiation effect that is still used as a possible evidence of
64 the embodied view of objects perception. This effect was first reported by Ellis and Tucker
65 (2000). The mere perception of manipulable objects usually grasped with a power-grip (e.g.,
66 an apple) and a precision-grip (e.g., a cherry) induces shorter response times (RTs) when
67 participants had to perform a compatible rather than an incompatible grip on an appropriate
68 device (e.g., Ellis & Tucker, 2000; Girardi, Lindemann & Bekkering, 2010; Makris, Hadar &
69 Yarrow, 2011; Tucker & Ellis, 2004). The proponents of several embodied views (e.g.,
70 Barsalou, 2008; Borghi & Riggio, 2015) argued that the perception of an object strongly
71 associated with a particular grip (e.g., an apple) leads to the automatic access to its associated
72 mental representations including a motor component. The automatic access to this motor
73 component would result in a motor preparation of the usual grip facilitating the execution of a
74 compatible grip and/or impairing the execution of an incompatible grip.

75 Even if this interpretation is shared by several researchers, some authors have developed an
76 alternative view. Proctor and Miles (2014) argued for instance, that this effect could be due to
77 an overlap of more abstract codes used to represent manipulable objects and response options.
78 They particularly argued that power- and precision-grip responses could be coded as large-
79 and small-responses, respectively. Such motor size codes would overlap the perceptual size
80 codes of the target/object. Indeed, objects usually grasped with a power-grip are also larger
81 than objects usually grasped with a precision-grip (e.g., an apple vs. a cherry). In the same
82 vein, Masson (2015) argued that “a more abstract type of compatibility (i.e., size)” explains

83 this potentiation effect rather than the activation of grasping motor representations when
84 perceiving the object. This interpretation is closed to that of the Theory of Event Coding
85 (TEC; Hommel et al., 2001; Hommel, 2013). In this view, Stimulus-Response-Compatibility
86 effects would be due to a match (or a mismatch) between spatial features used to code both
87 stimuli and responses. For instance, the Simon effect would be due to the use of the left/right
88 dimension to indifferently codes stimuli (i.e., located on the left or right side of the screen)
89 and responses (i.e., left or right hand; see Hommel, 2011 for a review). In the case of the
90 potentiation of grasping behaviors, the relevant spatial dimension would be the size (i.e., large
91 vs. small) instead of the left/right location.

92 Accordingly, this size-coding-hypothesis first requires that objects usually grasped with a
93 power- vs. precision-grip are automatically coded as large and small objects, respectively.
94 Some elements partially support this hypothesis. First, in most of the studies on the
95 potentiation effect of grasping behaviors, objects were presented in a visual size matching
96 their real size (e.g., Flumini, Barca, Borghi & Pezzulo, 2015; Kalénine, Shapiro, Flumini,
97 Borghi, & Buxbaum, 2014; Makris, Grant, Hadar & Yarrow, 2013; Makris, Hadar & Yarrow,
98 2011, 2013). Insofar as power-grip-related objects are generally larger than precision-grip-
99 related objects (e.g., an apple vs. a cherry), the firsts are thus visually larger than the seconds.
100 Such a visual difference could favor their relative coding as large and small objects. Second,
101 some studies suggested that the familiar size of objects can be automatically retrieved from
102 memory. For instance, Ferrier, Staudt, Reilhac, Jiménez and Brouillet (2007) reported that
103 objects associated with a large or small familiar size prime categorical judgments of objects
104 with a close familiar size compared to objects with an important size difference. It is
105 noteworthy that in this experiment, objects were presented with a constant visual size
106 supporting the critical involvement of the familiar size rather than the visual one (see also
107 Long, Konkle, Cohen & Alvarez, 2016; Long & Konkle, 2017 for converging evidences). In
108 sum, because power- and precision-grip-related objects both differed at the level of visual and
109 familiar (or semantic) size, both factors could favor the automatic size coding of both objects
110 categories.

111 Another critical requirement of the size-coding-hypothesis is that power- and precision-
112 grips are coded as large and small responses, respectively. According to the TEC (Hommel et
113 al., 2001; Hommel, 2013), alternative responses in a two alternative-forced-choice task are
114 coded thanks to spatial features allowing participants to distinguish between them. For
115 instance, evidence supports that responses could be coded along the left/right, far/near and
116 even up/down dimensions (see Hommel & Elsner, 2009 for a review). In accordance, it is
117 likely that the size could be another spatial feature used to code alternative responses. In the
118 particular case of power- vs. precision-grip, at least two components could favor this size
119 coding. First, in all previous experiments, researchers usually used two kinds of device
120 allowing participants to perform both grips. The most usual device is the one originally
121 introduced by Ellis and Tucker (2000). Interestingly, it is composed by a large switch pressed
122 thanks to a power-grip and a small switch pressed thanks to a precision grip (see Figure 1 of
123 Ellis & Tucker, 2000, p. 455). The other frequently used device is a wooden block made of a
124 large and a small part, and participants are usually instructed to grasp the large part with a
125 power-grip and the small part with a precision-grip (e.g., Girardi et al., 2010). For both

126 response devices, actual response alternatives differ according to the size of the targeted part
127 of the device. Second, it is also noteworthy that both grips differed thanks to the size of the
128 effectors part used. Indeed, when participants carry out a power-grip, they use their whole
129 hand (i.e., the large part) while when they carry out a precision-grip, they only used two
130 fingers (i.e., a smaller part). In sum, size coding of responses could occur because of the size
131 of switches and/or the size of the used parts of the effector, especially considering that in
132 experiments usually reporting a potentiation of grasping behaviors, a two alternative-forced-
133 choice task is always used.

134 To directly test the size-coding-hypothesis, we conducted four experiments. Our goal was
135 to experimentally induce a size coding of two non-grasping responses and to test if
136 manipulable objects (usually associated with a power- or precision-grip) would potentiate
137 them. More specifically, we used an experimental protocol known to induce a potentiation
138 effect of grasping behaviors (Heurley, Morgado, Brouillet & Coutté, submitted) but in which
139 participants had no longer to carry out a power- and a precision-grip. Instead, the device was
140 fixed horizontally on the table and participants had solely to press each of its switches as if
141 they were keys on a keyboard (i.e., the grasping component was removed). In Experiment 1,
142 participants had to press the small-switch with their index-digit and the large-switch with their
143 palm-hand. We selected these particular responses to maximize the possibility that
144 participants coded each response as large and small, respectively. Indeed, we manipulated
145 simultaneously two factors: the switch size (large *vs.* small) and the size of the effector part
146 used to press each switch (i.e., the index-digit: small *vs.* the palm-hand: large). According to
147 the size-coding-hypothesis, we predicted shorter Response Times (RTs) when the response
148 and the object sizes matched together than when they mismatched. In Experiment 2, 3 and 4,
149 we went further by investigating which factors of Experiment 1 allowed the size coding of
150 responses: (1) the size of switch and/or (2) the size of the effector part used to press each
151 switch.

152

153 **2. Experiment 1**

154 2.1. Method

155 *2.1.1. Participants*

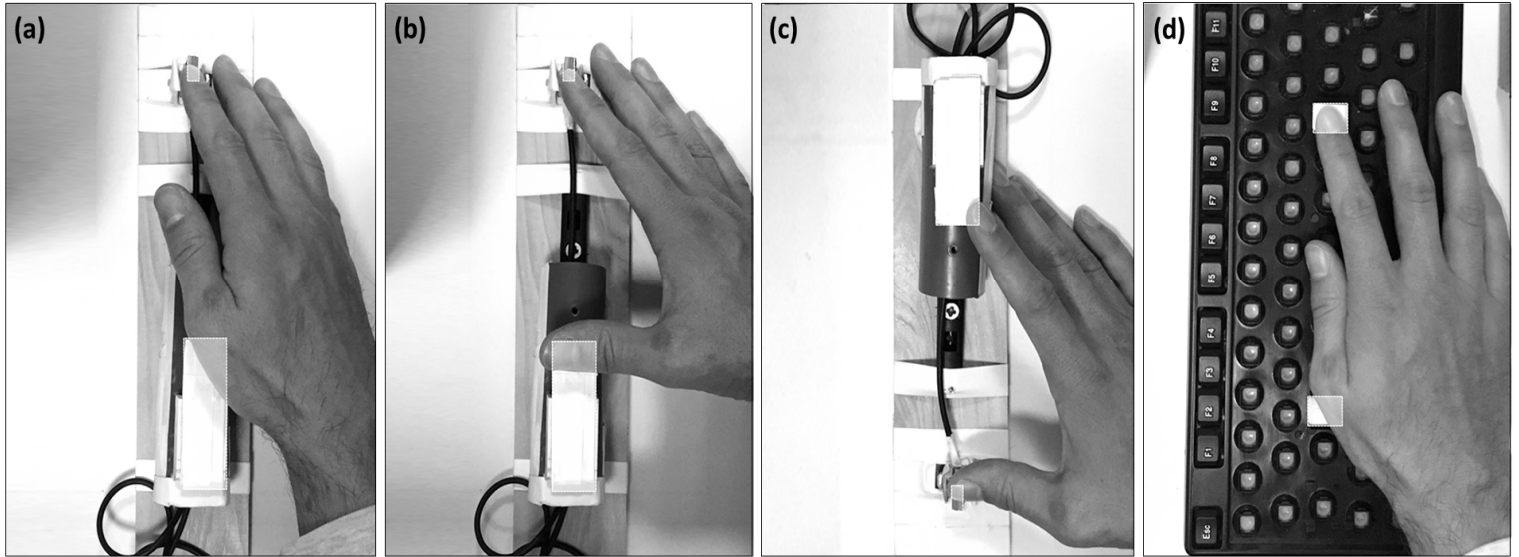
156 Twenty-two participants (6 females; 21 right-handed; $m_{\text{age}} = 19.6$ years; $s_{\text{age}} = 0.8$) with
157 normal or corrected-to-normal visual acuity and without color perception issues (e.g.,
158 colorblind) participated to the experiment. All participants were naïve to the goal of the
159 experiment.

160

161 *2.1.2. Materials and apparatus*

162 We used 12 pictures of fruits and vegetables: six of large fruits or vegetables usually
163 grasped with a power-grip (i.e., apple, avocado, banana, eggplant, lemon, and pear) and six of
164 small fruits or vegetables usually grasped with a precision-grip (i.e., cherry, grape, hazelnut,
165 peanut, radish, and strawberry). All pictures were presented against a white background and
166 in a visual size matching the actual size of the depicted fruits and vegetables (large objects \approx
167 10° of visual angle and small objects $\approx 3^\circ$). We more specifically designed three versions of
168 each picture (grayscale, blue and orange). These pictures were already used by Heurley et al.

169 (submitted) (see Appendix; to find all pictures used, see Heurley et al., 2020). We also used a
170 response device similar to the one originally used by Ellis and Tucker (2000). It was
171 composed of two parts: a small cube (1 cm³) containing a very small switch and a larger PVC
172 cylinder (10 cm tall and 3 cm in diameter) with a large switch placed to the free side of the
173 cylinder (Figure 1).



174

175 **Figure 1** Various kinds of response alternatives and their associated devices used in each experiment (seen from
176 above): (a) Experiment 1, (b) Experiment 2, (c) Experiment 3, and (d) Experiment 4. On each picture, when
177 switches were occulted by the hand, a white transparent square have been added to better understand where
178 switches were located, their size and how participants were instructed to press them.

179

180 2.1.3. Procedure

181 The experiment was run in a quiet room where each participant was seated facing a
182 monitor (23"; refresh rate: 60 Hz; placed at 60 cm). In order to ensure that each participant
183 correctly knew each fruit and vegetable, the experiment began with two preliminary phases.
184 In the first one, the twelve pictures were presented successively with the name of the
185 fruit/vegetable written below. Participants simply read aloud the name of each item. The
186 second was similar except that names were no longer presented below each picture (see Bub,
187 Masson & Cree, 2008, for a similar preparation). Then, a familiarization phase began. During
188 each trial, a fixation cross was first presented at the center of the screen (500 ms) followed by
189 a picture of a fruit/vegetable in grayscale for 200, 400, or 800 ms (Stimulus Onset
190 Asynchrony, SOA). Then, the fruit/vegetable turned orange or blue. The task was to
191 categorize, as soon as possible, the colors of the pictures. Participants were instructed to press
192 the large-switch with their palm-hand while they have to press the small-switch with their
193 index-digit. The device was fixed to a board, itself fixed on the table right in front of the
194 participant (Figure 1a). In addition, the experimenter explained to the participants the
195 mapping between colors and each response switch (i.e., large-switch for blue vs. small-switch
196 for orange; counterbalanced between participants). Following the response, a blank screen
197 appeared for 2500 ms. Both responses were recorded using E-prime 2.0 on an HP-Probook-
198 650G1 2.40 GHz computer. After the familiarization phase (24 trials), a test phase took place.

199 Each trial followed the same procedure. This phase was composed of 144 trials: eight test
200 pictures (cherry, grape, hazelnut, strawberry, apple, avocado eggplant, and pear) randomly
201 presented 18 times, nine times in blue and nine times in orange. There were 48 trials with
202 each prime duration (SOA = 200, 400 or 800 ms). Finally, participants completed a short
203 questionnaire and the Edinburgh Handedness Inventory (Veale, 2013).

204

205 2.2. Results and discussion

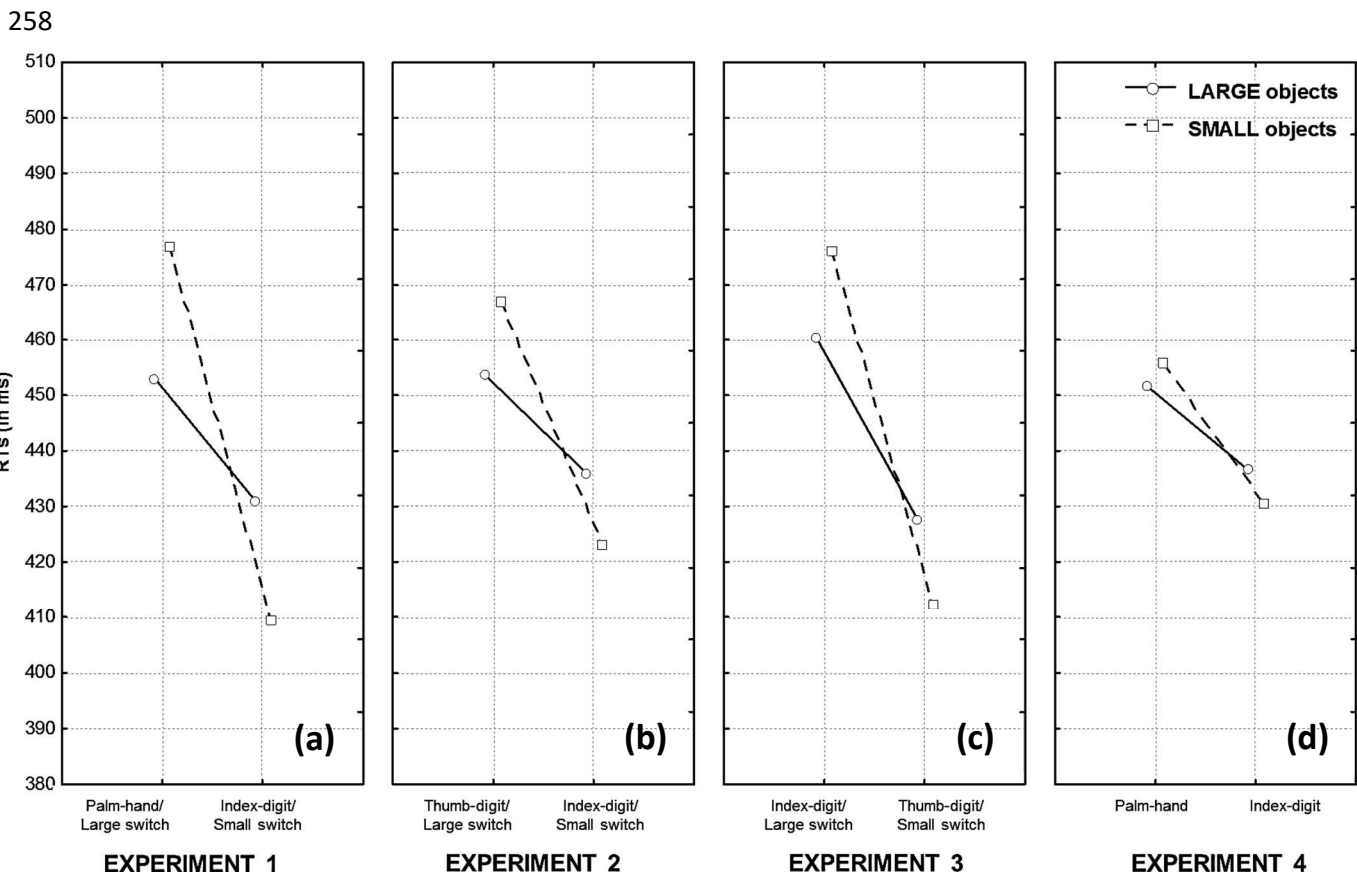
206 We examined the RTs with a mixed-design ANOVA with participants as a random factor,
207 the size of objects (large vs. small), the responses type (palm-hand/large-switch vs. index-
208 digit/small-switch), the SOA (200 ms vs. 400 ms vs. 800 ms) as within-subject factors and the
209 mapping (large-switch/blue vs. small-switch/blue) as a between-subject factor. We only
210 analyzed RTs because there were too few errors to analyze response accuracy. Accordingly,
211 we removed familiarization trials, incorrect trials (2.01% of data), and trials for which
212 participants' RTs were below 200 ms or above 1200 ms (0.14% of data) from the analyses (to
213 find all raw data and all analysis performed, see Heurley et al., 2020).

214 The ANOVA revealed a statistically significant main effect of SOA, $F(2, 20) = 67.76, p <$
215 $.001, \eta_p^2 = 0.77$. According to the corrected significance threshold (corrected test-wise $\alpha = .02$
216 after a Bonferroni correction considering a family of three comparisons), comparisons
217 showed that RTs were significantly longer in the 200 ms-SOA condition ($m = 468$ ms; $s = 58$)
218 than 400 ms-SOA condition ($m = 434$ ms; $s = 53$), $F(1, 20) = 66.33, p < .001, \eta_p^2 = 0.77$, and
219 significantly longer in the 200 ms than in the 800 ms-SOA condition ($m = 426$ ms; $s = 53$),
220 $F(1, 20) = 113.48, p < .001, \eta_p^2 = 0.85$. In addition, RTs were marginally longer in the 400
221 ms-SOA condition than in the 800 ms-SOA, $F(1, 20) = 5.34, p = .03, \eta_p^2 = 0.21$. The ANOVA
222 also revealed a statistically significant main effect of response type, $F(1, 20) = 27.17, p <$
223 $.001, \eta_p^2 = 0.58$. Indeed, RTs were significantly longer when participants pressed the large-
224 switch with their palm-hand ($m = 465$ ms; $s = 58$) than when they pressed the small-switch
225 with their index-digit ($m = 420$ ms; $s = 48$). Interestingly, the ANOVA revealed a statistically
226 significant interaction between the size of the objects and responses type, $F(1, 20) = 41.83, p$
227 $< .001, \eta_p^2 = 0.68$. Based on the corrected significance threshold (corrected test-wise $\alpha = .03$
228 after a Bonferroni correction considering a family of two comparisons), planned comparisons
229 showed that palm-hand/large-switch RTs were shorter for large objects ($m = 453$ ms; $s = 52$)
230 than for small ones ($m = 477$ ms; $s = 62$), $F(1, 20) = 26.01, p < .001, \eta_p^2 = 0.57$. Conversely,
231 index-digit/small-switch RTs were faster for small objects ($m = 409$ ms; $s = 41$) than for the
232 large ones ($m = 431$ ms; $s = 51$), $F(1, 20) = 16.00, p < .001, \eta_p^2 = 0.44$ (Figure 2a). The
233 ANOVA failed to reveal any other main effects or interactions, especially the three-way
234 interaction between SOA, size of objects, and response types, $F(2, 20) = 1.22, p = .31, \eta_p^2 =$
235 0.06 .

236 Our results confirmed our main prediction. Responses that were possibly coded as large
237 were facilitated by large compared with small objects and the reverse pattern was true for
238 responses that were possibly coded as small. Such results strongly support the size-coding
239 hypothesis. Indeed, it seems that large objects usually associated with a power-grip and small
240 objects usually associated with a precision-grip can potentiate non-grasping manual responses

241 coded respectively as large and small and not only compatible grasping behaviors. In
 242 Experiment 2, we wanted to go further and to test more directly whether the size coding of
 243 responses relies mainly on the size of switches or on the size of effector parts used. Therefore,
 244 we instructed participants to press the small-switch with their index-digit and the large-switch
 245 with their thumb-digit (Figure 1b). While there is a clear difference of size between the index-
 246 digit and the palm-hand, it is no longer the case between the index- and the thumb-digit. If the
 247 size coding of responses is due to the switch size, we should still observe a potentiation effect
 248 despite that the used effectors were comparable in size.

249 Furthermore, it is noteworthy that Experiment 1 led to two other effects of a secondary
 250 importance. First, the longer the SOA was, the shorter RTs were. Such a facilitation was
 251 already reported in experiments using a similar protocol (e.g., Ferrier et al., submitted).
 252 Longer SOA presumably allowed a longer action preparation resulting in shorter RTs.
 253 Second, we observed that RTs were shorter when participants pressed the small-switch with
 254 their index-digit compared to the condition where they pressed the large-switch with their
 255 palm-hand. Such a difference could come from (1) a difference between latencies of each
 256 switch, (2) a difference between using the index-digit and the palm-hand or (3) both factors.
 257 Next experiments were also designed to address these alternative explanations.



273

274 **Figure 2** Mean RTs (ms) according to the size of objects (large vs. small), the responses type (varying in each
 275 experiment), and experiments: (a) Experiment 1 (palm-hand/large-switch vs. index-digit/small-switch); (b)
 276 Experiment 2 (index-digit/small-switch vs. thumb-digit/large-switch); (c) Experiment 3 (index-digit/large-switch
 277 vs. thumb-digit/small-switch); and (d) Experiment 4 (palm-hand vs. index-digit).

279 3. Experiment 2

280 3.1. Method

281 Twenty-two participants (5 females; 18 right-handed; $m_{age} = 19.8$ years; $s_{age} = 0.8$), all
282 naïve to the experiment's goal, with normal or corrected-to-normal visual acuity and without
283 any color perception issues participated to the experiment. We used exactly the same pictures,
284 response device and procedure as in Experiment 1. The only difference was that we instructed
285 participants to press the large-switch with their thumb-digit (and not with their palm-hand)
286 and the small-switch with their index-digit (Figure 1b).

287

288 3.2. Results and discussion

289 As in Experiment 1, we conducted a mixed-design ANOVA on RTs with participants as a
290 random factor, the size of objects (large vs. small), the responses type (thumb-digit/large-
291 switch vs. index-digit/small-switch), the SOA (200 ms vs. 400 ms vs. 800 ms) as within-
292 subject factors and the mapping (large-switch/blue vs. small-switch/blue) as a between-
293 subject factor. We removed familiarization trials, incorrect trials (2.24% of data), and trials
294 for which each participant's RTs were below 200 ms or above 1200 ms (0.22% of data) from
295 the analyses.

296 The ANOVA revealed a statistically significant main effect of SOA, $F(2, 20) = 43.52$, $p <$
297 $.001$, $\eta_p^2 = 0.69$. According to the corrected significance threshold (corrected test-wise $\alpha = .02$
298 after a Bonferroni correction considering a family of three comparisons), RTs were
299 significantly longer in the 200 ms-SOA condition ($m = 469$ ms; $s = 66$) than in the 400 ms-
300 SOA condition ($m = 437$ ms; $s = 60$), $F(1, 20) = 45.57$, $p < .001$, $\eta_p^2 = 0.69$, as well as than in
301 the 800 ms-SOA condition ($m = 429$ ms; $s = 57$) was significant, $F(1, 20) = 69.92$, $p < .001$,
302 $\eta_p^2 = 0.78$. RTs were marginally longer in the 400 ms-SOA condition than in the 800 ms-SOA
303 condition, $F(1, 20) = 5.34$, $p = .03$, $\eta_p^2 = 0.21$, $F(1, 20) = 3.86$ $p = .06$, $\eta_p^2 = 0.16$. The main
304 effect of response type was also statistically significant, $F(1, 20) = 20.28$, $p < .001$, $\eta_p^2 = 0.50$.
305 RTs were significantly longer when participants pressed the large-switch with their thumb-
306 digit ($m = 460$ ms; $s = 64$) than when they pressed the small-switch with their index-digit ($m =$
307 430 ms; $s = 59$). More important, the interaction between the size of the objects and response
308 type was statistically significant, $F(1, 20) = 18.85$, $p < .001$, $\eta_p^2 = 0.49$. Thumb-digit/large-
309 switch RTs were shorter for large objects ($m = 454$ ms; $s = 63$) than for small ones ($m = 467$
310 ms; $s = 65$), $F(1, 20) = 8.68$, $p = .008$, $\eta_p^2 = 0.30$. Conversely, index-digit/small-switch RTs
311 were shorter for small objects ($m = 423$ ms; $s = 55$) than for large ones ($m = 436$ ms; $s = 62$),
312 $F(1, 20) = 4.91$, $p = .04$, $\eta_p^2 = 0.20$ (Figure 2b). Nevertheless, this last comparison was no
313 longer statistically significant after applying Bonferroni correction even if it fell very close to
314 the corrected threshold (corrected test-wise $\alpha = .03$ after a Bonferroni correction considering a
315 family of two planned comparisons). In addition, the ANOVA also revealed that the three-
316 way interaction between SOA, size of objects and response types was statistically significant,
317 $F(2, 20) = 10.84$, $p < .001$, $\eta_p^2 = 0.35$ (for all panned comparisons, see Table 1). No other
318 main or interaction effects were statistically significant.

319

320 **Table 1** Results of performed planned comparisons on RTs (in ms) between conditions where large and small
 321 objects were presented for each SOA (200, 400 and 800 ms) and for each response types (thumb-digit/large-
 322 switch *vs.* index-digit/small-switch). We report RTs mean in ms (standard deviation), the F details and if there is
 323 a significant or a non-significant effect (S and NS respectively) according to the corrected significance threshold
 324 (corrected test-wise $\alpha = .008$ after a Bonferroni correction considering a family of six planned comparisons).
 325

SOA	Response types	Large objects	Small objects	F data			
200 ms	Thumb-digit/large-switch	471 (61)	505 (54)	F(1, 20) = 13.49	p = .002	$\eta_p^2 = 0.40$	S
	Index-digit/small-switch	468 (72)	433 (55)	F(1, 20) = 9.06	p = .007	$\eta_p^2 = 0.31$	S
400 ms	Thumb-digit/large-switch	447 (69)	454 (66)	F(1, 20) = 0.57	p = .57	$\eta_p^2 = 0.03$	NS
	Index-digit/small-switch	429 (52)	418 (44)	F(1, 20) = 1.31	p = .27	$\eta_p^2 = 0.06$	NS
800 ms	Thumb-digit/large-switch	443 (55)	443 (56)	F(1, 20) = 0.01	p = .93	$\eta_p^2 = 0.00$	NS
	Index-digit/small-switch	412 (46)	418 (63)	F(1, 20) = 0.52	p = .48	$\eta_p^2 = 0.03$	NS

326
 327 Taken together these data support the possibility that the size coding of responses (and in
 328 turn the potentiation effect) could merely come from a difference in the size of targeted
 329 switches. Indeed, in the present experiment, the size of the used effector parts remained
 330 constant because participants had to use their index- and their thumb-digit to respond.
 331 Interestingly, the potentiation effect was moderated by the SOA. More specifically, the effect
 332 only occurred for a 200 ms-SOA condition. We will discuss more specifically this moderation
 333 in the “General Discussion” section according to the results of the three other experiments.

334 A possible limit of Experiment 2 is that some participants could code their thumb-digit as
 335 larger than their index-digit. If so, the sizes of switches and of effector parts used were still
 336 confounded. Thus, we ran a new experiment to better dissociate both factors. Our strategy was
 337 to reverse the mapping between the size of switches and responses. More precisely,
 338 participants had to press the small-switch with their thumb-digit and to press the large-switch
 339 with their index-digit. Accordingly, opposite predictions could be made. If the size coding
 340 and, in turn, the potentiation effect were due to the size of switches, seeing large objects
 341 should facilitate pressing the large-switch with the index-digit compared with seeing small
 342 objects. Moreover, seeing small objects should facilitate pressing the small-switch with the
 343 thumb-digit compared with seeing large objects. In contrast, if the size coding and, in turn, the
 344 potentiation effect were due to the size of the used effector part, seeing large objects should
 345 facilitate pressing the small-switch with the thumb-digit (i.e., the larger effector part)
 346 compared with seeing small objects. Moreover, seeing small objects should facilitate pressing
 347 the large-switch with the index-digit (i.e., the smaller effector part) compared with seeing
 348 large objects.

349 4. Experiment 3

351 4.1. Method

352 Twenty-two participants (5 females; 20 right-handed; $m_{age} = 20.3$ years; $s_{age} = 1.7$)
 353 participated to this experiment. They were all naïve to the goal of the experiment and with
 354 normal or corrected-to-normal visual acuity as well as without color perception issues. The
 355 experiment was similar to Experiment 2 except that we instructed participants to press the
 356 large-switch with their index-digit and the small-switch with their thumb-digit (Figure 1c).

357

358 4.2. Results and discussion

359 We conducted a mixed-design ANOVA on RTs with participants as a random factor, the
360 size of objects (large vs. small), the responses type (thumb-digit/small-switch vs. index-
361 digit/large-switch), the SOA (200 ms vs. 400 ms vs. 800 ms) as within-subject factors and the
362 mapping (large-switch/blue vs. small-switch/blue) as a between-subject factor. We removed
363 familiarization trials, incorrect trials (2.38% of data), and trials for which each participant's
364 RTs were below 200 ms or above 1200 ms (0.42% of data) from the analyses.

365 The ANOVA revealed a statistically significant main effect of SOA, $F(2, 20) = 37.60, p <$
366 $.001, \eta_p^2 = 0.65$. According to the corrected significance threshold (corrected test-wise $\alpha = .02$
367 after a Bonferroni correction considering a family of three comparisons), RTs were
368 significantly longer in the 200 ms-SOA condition ($m = 464$ ms; $s = 67$) than in 400 ms-SOA
369 condition ($m = 438$ ms; $s = 76$), $F(1, 20) = 39.02, p < .001, \eta_p^2 = 0.66$, and significantly longer
370 in the 200 ms than in the 800 ms-SOA condition ($m = 430$ ms; $s = 69$), $F(1, 20) = 66.34, p <$
371 $.001, \eta_p^2 = 0.77$. In addition, RTs were marginally longer in the 400 ms-SOA condition than in
372 the 800 ms-SOA condition, $F(1, 20) = 4.55, p = .04, \eta_p^2 = 0.19$. A main effect of response type
373 was also statistically significant, $F(1, 20) = 16.51, p < .001, \eta_p^2 = 0.45$. RTs were significantly
374 longer when participants pressed the large-switch with their index-digit ($m = 468$ ms; $s = 67$)
375 than when they pressed the small-switch with their thumb-digit ($m = 420$ ms; $s = 69$). The
376 interaction between the size of the objects and responses type was statistically significant,
377 $F(1, 20) = 9.14, p = .007, \eta_p^2 = 0.31$. RTs when participants pressed the large-switch with their
378 index-digit were significantly shorter for large objects ($m = 460$ ms; $s = 61$) than for small
379 ones ($m = 476$ ms; $s = 72$), $F(1, 20) = 6.86, p = .02, \eta_p^2 = 0.26$. RTs when participants pressed
380 the small-switch with their thumb were shorter for small objects ($m = 412$ ms; $s = 69$) than for
381 large ones ($m = 428$ ms; $s = 67.50$), $F(1, 20) = 4.55, p = .04, \eta_p^2 = 0.19$ (Figure 2c).
382 Nevertheless, this last comparison was no longer statistically significant after applying
383 Bonferroni correction even if it fell very close to the corrected threshold (corrected test-wise α
384 $= .03$ after a Bonferroni correction considering a family of two planned comparisons).
385 Moreover, the ANOVA did not reveal any other statistically significant main or interaction
386 effects¹, especially the three-way interaction between SOA, size of objects and response
387 types, $F(2, 20) = 0.48, p = .62, \eta_p^2 = 0.02$.

388 The results suggested a potentiation effect in the present experiment. Interestingly, such
389 effect supports that the size coding was driven by the size of switches and not by the size of
390 effector used (i.e., digit). Indeed, the facilitation of responses occurred according to the
391 matching between the sizes of objects and switches and not according to the matching
392 between the sizes of objects and digits. For instance, large objects facilitated a response on the
393 large-switch even if participants used the index-digit. Therefore, even if one could argue that

¹ It is noteworthy that the ANOVA revealed a statistically significant three-way interaction between the SOA, the response types, and the mapping that is not directly relevant for our main purpose. Indeed, for each mapping and each SOA, difference between RTs reach the significance threshold (all $p < 0.05$) except when the mapping was large-switch-blue and the SOA was 400 ms, $F(1, 20) = 3.35, p = .08, \eta_p^2 = 0.14$, and when the mapping was small-switch-blue and the SOA was 800 ms, $F(1, 20) = 4.28, p = .05, \eta_p^2 = 0.18$.

394 a size difference could be used to discriminate the index- and the thumb-digit, the effect was
395 nevertheless drove by the switch's size. Furthermore, it is also noteworthy that the
396 potentiation effect was not moderated by the SOA unlike in Experiment 2. Even if
397 Experiments 2 and 3 suggest that the size coding of responses may rely on the size of
398 switches, the size of the used effector parts could also matter in some situations like in our
399 Experiment 1. Indeed, the size difference between the palm-hand and the index-digit was
400 maybe more salient than those between the index and the thumb, which could also have
401 favored the size coding of responses. Accordingly, we conducted a fourth experiment in
402 which we selected switches with a similar size (i.e., keyboard keys) and where participants
403 were instructed to press them either with their palm-hand or index-digit. If a size difference
404 between the used effector parts promotes the size coding of response, a potentiation effect
405 should be observed.

406

407 **5. Experiment 4**

408 5.1. Method

409 As in previous experiments, 22 participants (five females; 18 right-handed; $m_{\text{age}} = 19.8$
410 years; $s = 1.3$) participated in the experiment. All were naïve about its goal, had normal or
411 corrected-to-normal visual acuity, and did not report any color perception issues. Originally,
412 our sample included 22 participants, but two participants were discarded due to instruction
413 disrespect. In order to avoid a difference that could possibly undermine the statistical power
414 of the present experiment compared to the three others, we recruited two additional
415 participants. We used the same apparatus and procedure as in our previous experiments
416 except that participants no longer replied on a device composed by large and small switches
417 but on two keys of an AZERTY keyboard. Participants were instructed to press the S key with
418 their palm-hand and the L key with their index-digit (all the other keys have been removed;
419 Figure 1d). It is noteworthy that both keys have a similar size.

420

421 5.2. Results and discussion

422 We conducted a mixed-design ANOVA on RTs with participants as a random factor, the
423 size of objects (large vs. small), the responses type (palm-hand vs. index-digit), the SOA (200
424 ms vs. 400 ms vs. 800 ms) as within-subject factors and the mapping (palm-hand/blue vs.
425 index-digit/blue) as a between-subject factor. We removed familiarization trials, incorrect
426 trials (2.26% of data), and trials for which each participant's RTs were below 200 ms or
427 above 1200 ms (0.30% of data) from the analyses.

428 The ANOVA only revealed two statistically significant main effects. First, there was a
429 significant main effect of SOA, $F(2, 20) = 19.20$, $p < .001$, $\eta_p^2 = 0.49$. Based on the corrected
430 significance threshold (corrected test-wise $\alpha = .02$ after a Bonferroni correction considering a
431 family of three comparisons), RTs were significantly longer in the 200 ms-SOA condition (m
432 = 461 ms; $s = 54$) than in the 400 ms-SOA condition ($m = 440$ ms; $s = 56$), $F(1, 20) = 15.97$, p
433 $< .001$, $\eta_p^2 = 0.44$, and were significantly longer in the 200 ms than in the 800 ms-SOA
434 condition ($m = 429$ ms; $s = 50$), $F(1, 20) = 39.91$, $p < .001$, $\eta_p^2 = 0.61$. In addition, RTs were
435 marginally longer in the 400 ms-SOA condition than in the 800 ms-SOA condition, $F(1, 20) =$

436 5.80, $p = .03$, $\eta_p^2 = 0.22$. Second, there was a significant main effect of response type, $F(1, 20)$
437 $= 7.59$, $p = .02$, $\eta_p^2 = 0.28$. RTs were longer when participants pressed the key with their
438 palm-hand ($m = 454$ ms; $s = 57$) than when they pressed the other key with their index-digit
439 ($m = 433$ ms; $s = 51$). Interestingly, the ANOVA did not reveal any other statistically
440 significant main or interaction effects. Especially, the Object Size x Response Type
441 interaction was not statistically significant, $F(1, 20) = 1.06$, $p = .32$, $\eta_p^2 = .05$ (Figure 2d).
442 Despite of this lack of statistical significance, the patterns of results was consistent with the
443 presence of this interaction, at least in our sample. RTs when participants responded with their
444 index-digit were shorter for small objects ($m = 430$ ms; $s = 50$) than for large ones ($m = 437$
445 ms; $s = 52$), $F(1, 20) = 1.03$, $p = .32$, $\eta_p^2 = .05$. RTs when participants responded with their
446 palm-hand were shorter for large objects ($m = 452$ ms; $s = 57$) than for small ones ($m = 455$
447 ms; $s = 58$), $F(1, 20) = 0.48$, $p = .50$, $\eta_p^2 = .02$. However, both comparisons failed to reach the
448 significance threshold corrected for multiple comparisons (corrected test-wise $\alpha = .03$ after a
449 Bonferroni correction considering a family of two comparisons). Moreover, the SOA x Object
450 Size x Response Type interaction also failed to reach the significance threshold, $F(2, 20) =$
451 0.48 , $p = .62$, $\eta_p^2 = .02$. Implications of these last results are directly discussed in the general
452 discussion.

453

454 **6. Additional analyses**

455 To go further and to better understand the reported data, we conducted three additional
456 analyses. The first compared the size of the potentiation effect between Experiment 1 and 2.
457 The second aimed to compare the potentiation effect between Experiment 2 and 3. The last
458 was a power analysis used to investigate whether our sample size was large enough to
459 properly detect a potentiation effect.

460

461 6.1. Cross-experiment analysis between Experiment 1 and 2

462 Our four experiments convincingly support the hypothesis that a difference in the switch
463 size can lead to a potentiation effect. Indeed, even when the grasping component of responses
464 was removed, merely seeing small and large manipulable objects still facilitated responses on
465 a small- and large-switch, respectively (see Experiment 1, 2, and 3). The effector size did not
466 seem to matter (see Experiment 4). Nevertheless, the size of the observed potentiation effect
467 varied across the experiments. Especially, the potentiation-effect size reported in Experiment
468 1 (i.e., $m = 23$ ms; $s = 16$; $\eta_p^2 = 0.68$) was larger than the potentiation-effect size reported in
469 Experiment 2 (i.e., $m = 13$ ms; $s = 14$; $\eta_p^2 = 0.49$). Thus, even if the switch can lead to a
470 potentiation effect, the effector size could also matter. Maybe both independent variables have
471 contributed to the effect size in Experiment 1. To investigate this possibility, we conducted a
472 cross-experiment analysis specifically dedicated to test the effect-size differences between
473 Experiments 1 and 2.

474

475 6.1.1. Method

476 We computed a potentiation effect by participant for each experiment ($n_{\text{Experiment 1}} =$
477 $n_{\text{Experiment 2}} = 22$). More precisely, we subtracted mean RTs in compatible conditions to the
478 mean RTs in non-compatible conditions. Accordingly, positive values represented a
479 facilitation effect in compatible conditions (compared with the compatible ones, what we
480 called “potentiation effect”) while negative values represented a facilitation effect in non-
481 compatible conditions (compared with compatible ones).

482

483 6.1.2. Results and discussion

484 We conducted a mixed-design ANOVA on the size of the potentiation effect with
485 participants as a random factor, the SOA (200 ms vs. 400 ms vs. 800 ms) as a within-subject
486 factor and the experiment (Experiment 1 vs. Experiment 2) as a between-subjects factor. We
487 did not include the mapping (palm-hand/blue vs. index-digit/blue) because it never moderated
488 the potentiation effect in the previous analyses. As we did before, familiarization trials,
489 incorrect trials, and trials for which each participant’s RTs were below 200 ms or above 1200
490 ms were removed from the analyses. We didn’t apply a filtering on the size of the potentiation
491 effects themselves.

492 Interestingly, the ANOVA revealed a statistically significant main effect of experiments,
493 $F(1, 42) = 4.26, p = .045, \eta_p^2 = 0.09$. More precisely, the size of the potentiation effect
494 observed in Experiment 1 ($m = 23$ ms; $s = 16$) was significantly larger than the one observed
495 in Experiment 2 ($m = 13$ ms; $s = 14$). The ANOVA also revealed a statistically significant
496 main effect of SOA, $F(2, 42) = 7.85, p < .001, \eta_p^2 = 0.16$. First, according to the corrected
497 significance threshold (corrected test-wise $\alpha = .02$ after a Bonferroni correction considering a
498 family of three comparisons), the size of the potentiation effect in the 200 ms-SOA condition
499 ($m = 31$ ms; $s = 23$) was marginally larger than the one in the 400 ms-SOA condition ($m = 18$
500 ms; $s = 20$), $F(1, 42) = 4.52, p = .04, \eta_p^2 = 0.10$, which was marginally smaller than the one in
501 the 800 ms-SOA condition ($m = 5$ ms; $s = 18$), $F(1, 43) = 4.12, p = .049, \eta_p^2 = 0.09$. However,
502 the size of the potentiation effect was significantly larger in the 200 ms-SOA condition than in
503 the 800 ms-SOA condition, $F(1, 42) = 13.28, p < .001, \eta_p^2 = 0.24$. Because the size of the
504 potentiation effect progressively decreased as SOA increased, we compared the size of the
505 potentiation effect to 0 for each SOA. Our goal was to test if the potentiation effect was still
506 statistically significant at 800 ms-SOA. Interestingly, the size of the potentiation effect
507 differed significantly from 0 in the 200 ms-SOA ($F(1, 42) = 34.98, p < .001, \eta_p^2 = 0.45$) and
508 400 ms-SOA ($F(1, 42) = 18.22, p < .001, \eta_p^2 = 0.30$) conditions but not in the 800 ms-SOA
509 conditions ($F(1, 42) = 1.87, p = .18, \eta_p^2 = 0.04$). This last result suggests a disappearance of
510 the potentiation effect at 800 ms-SOA.

511 Finally, the SOA x Experiment interaction failed to reach the significance threshold, $F(2,$
512 $42) = 2.20, p = .12, \eta_p^2 = 0.05$. The results of this analysis are discussed in the “General
513 Discussion” in light of the other analyses.

514

515 6.2. Cross-experiment analysis between Experiment 2 and 3

516 We compared Experiment 2 and 3 to overcome a limitation of separate analyses and to
517 better support the size-coding account. Indeed, in both experiments, the potentiation effect
518 was statistically significant when participants had to use the large-switch (whatever the
519 effector-part used). More precisely, participants were faster when they saw a large than a
520 small object. We observed the reversed pattern when participants had to use the small-switch
521 (whatever the effector-part used). Nevertheless, this last difference failed to reach the
522 statistical significance threshold corrected for multiple comparisons in Experiments 2 and 3.
523 In the present analysis, we combined data from both experiments in order to increase our data
524 set. We expected a statistically significant potentiation effect for both responses as predicted
525 by the size-coding account.

526

527 6.2.1. Method

528 We combined data sets of Experiment 2 and 3. Thus, we had a total of 44 participants
529 ($n_{\text{Experiment 2}} = n_{\text{Experiment 3}} = 22$).

530 6.1.2. Results and discussion

531 We conducted a mixed-design ANOVA on RTs with participants as a random factor, the
532 size of objects (large vs. small), the responses type (large-switch vs. small-switch) as within-
533 subject factors and the experiment (Experiment 2 vs. Experiment 3) as a between-subjects
534 factor. We did not include the mapping nor the SOA because we did not have any specific
535 predictions for these variables. As we did before, familiarization trials, incorrect trials, and
536 trials for which each participant's RTs were below 200 ms or above 1200 ms were removed
537 from the analyses.

538 The ANOVA revealed a statistically significant main effect of response type, $F(1, 42) =$
539 $34.52, p < .001, \eta_p^2 = 0.45$. RTs were significantly longer when participants pressed the large-
540 switch whatever the effector ($m = 464$ ms; $s = 59$) than when they pressed the small-switch (m
541 $= 425$ ms; $s = 56$). The ANOVA failed to reveal either a statistically significant main effect of
542 the experiment, $F(1, 42) = 0.00, p = .96, \eta_p^2 = 0.00$, or of the size of objects, $F(1, 42) = 0.01, p$
543 $= .94, \eta_p^2 = 0.00$. As expected, the ANOVA revealed a statistically significant interaction
544 between the size of the objects and the responses type, $F(1, 42) = 24.24, p < .001, \eta_p^2 = 0.37$.
545 Based on the corrected significance threshold (corrected test-wise $\alpha = .03$ after a Bonferroni
546 correction considering a family of two comparisons), planned comparisons showed that large-
547 switch RTs were shorter for large objects ($m = 457$ ms; $s = 56$) than for small ones ($m = 472$
548 ms; $s = 60$), $F(1, 42) = 15.67, p < .001, \eta_p^2 = 0.27$. Conversely, small-switch RTs were faster
549 for small objects ($m = 417$ ms; $s = 56$) than for the large ones ($m = 432$ ms; $s = 56$), $F(1, 42) =$
550 $9.77, p < .003, \eta_p^2 = 0.19$. The ANOVA failed to reveal any other statistically significant
551 interactions, especially the three-way interaction between the experiment, the size of objects
552 and the response, $F(2, 42) = 0.17, p = .68, \eta_p^2 = 0.00$.

553 Accordingly, increasing our data set by merging data of Experiment 2 and 3 revealed that a
554 potentiation could be statistically significant for both response possibilities. It is also
555 interesting to note that the mean size of the potentiation effect (i.e., the difference between
556 non-compatible and compatible conditions) was approximately the same for responses
557 performed on the large-switch ($m = +15$ ms; $s = 24$) and responses performed on the small-

558 switch ($m = +14$ ms; $s = 30$) while there was a difference between the partial eta square (η_p^2)
559 for large-switch = 0.27 vs. η_p^2 for small-switch = 0.19). This peculiar pattern will be discussed
560 in the general discussion.

561

562 6.3. Power analysis

563 One could argue that our experiments were underpowered. This is a legitimate concern
564 given that we planned our sample size based on those of previous studies rather than
565 conducting a power or precision analysis. Thus, we assessed whether our research design
566 could detect our effect of interest with proper statistical power given our sample size using
567 G*Power 3 (Faul, Erdfelder, Lang, & Buchner, 2007). Our smallest effect of theoretical
568 interest was the Object Size x Response Type interaction effect on RTs. As it is often difficult
569 to know what particular value of effect size to include in a power analysis, we conducted
570 several power analyses allowing to have a range of possible values of statistical power rather
571 than just one value. This approach is more sensitive than considering only one value as it
572 better reflects the uncertainty inherent to all power analyses than relying only on a single
573 value.

574 We conducted a random-model meta-analysis using ESCI (Cumming, 2012) to better
575 estimate the size of the Object Size x Response Type interaction effect on RTs. Including our
576 four experiments resulted in a *Hedges' g* = 0.93, 95% CI for δ = [0.17, 1.78]. As predicted
577 given the differences in research design for some of our experiments, including all four
578 experiments led to a very large overall between- experiment heterogeneity ($I^2 = 88.66\%$)².

579 Thus, the meta-analytical effect size could have underestimated the true effect because of
580 the relatively small effect observed in Experiment 4. Including the first three experiments
581 resulted in a *Hedges' g* = 1.25, 95% CI for δ = [0.79, 1.81]. However, the overall between-
582 study heterogeneity ($I^2 = 55.23\%$) was still large, which was predictable according to the
583 relatively larger effect size observed in Experiments 1. Finally, including only Experiments 2
584 and 3 yielding a *Hedges' g* = 1.02, 95% CI for δ = [0.68, 1.44] with virtually no between-
585 experiment heterogeneity ($I^2 = 0.00\%$). Regular power analyses indicated that our research
586 design had a statistical power of 98.66%, 99.99%, and 99.53% to detect these effects,
587 respectively (two-tailed repeated measure test, $\alpha = .05$) with a sample size of 22 participants
588 (for all results, see Table 2).

589 To avoid being too optimistic, we also conducted safeguard power analyses (Perugini,
590 Gallucci, & Costantini, 2014) using the lower limit of the 60% CI of the effect sizes as our
591 smallest effect sizes of interest. For such worst-cases scenarios, the analyses indicated that our
592 research design had a statistical power of 79.95%, 99.80%, and 98.01% to detect effects as
593 large as *Hedges' g* = 0.63, 1.08, and 0.90, respectively (two-tailed repeated measure test, $\alpha =$
594 $.05$). Thus, given our current knowledge about our minimum effect size of interest, our
595 research design had reasonable chance to detect it even in the worst-case scenario (i.e.,
596 79.95% statistical power).

² As Cumming (2012, p. 217) reminded I^2 expresses the amount of between-experiments variability (over the total variability) that cannot be explained by random sampling error and reflect actual differences in the effect sizes that could be rather explained by actual differences between research designs.

597
598
599

Table 2 Results of the regular and safeguard power analyses according to various potential values of the expected effect size.

	REGULAR POWER ANALYSES			SAFEGUARD POWER ANALYSES		
Meta-analysis	Expe. 1 to 4	Expe. 1 to 3	Expe. 2 & 3	Expe. 1 to 4	Expe. 1 to 3	Expe. 2 & 3
Effect size	0.93	1.25	1.02	<i>0.62</i>	1.08	0.90
Power (%)	98.66	99.99	99.53	<i>79.95</i>	99.90	98.02

600 Note. The most plausible scenario and the worst-case scenario according to our current data are highlighted in
601 bold and italic fonts, respectively.
602

603 7. General Discussion

604 Our goal was to test whether the potentiation of grasping behaviors (e.g., Ellis & Tucker,
605 2000) can be explained by an overlap of a size code indifferently used to represent
606 manipulable objects and responses. Such a size-coding-hypothesis is clearly opposed to the
607 idea that potentiation effect relies on the activation of grasping motor representations during
608 the mere perception of manipulable objects as argued in various embodied views (e.g.,
609 Barsalou, 2008). Results of our four experiments strongly support the size-coding-hypothesis.
610 Indeed, in our experiments the performed responses were no longer grasping behaviors
611 compatible or not with presented objects, but mere keypress responses associated to different
612 sizes codes. Despite of this, graspable objects still elicited a potentiation effect. More
613 precisely, when participants had to press a large-switch, shorter RTs occurred when large
614 manipulable objects were presented (e.g., an apple) than when small manipulable objects
615 (e.g., a cherry) were. We obtained a reverse pattern when participants had to press a small-
616 switch. In sum, data reported support the critical hypothesis that manipulable objects do not
617 only facilitate power- and precision-grip-responses but also more classical keypress responses
618 when they are associated with a large/small size code.

619 Our various experiments also support that the size coding of responses critically relies on
620 the size of the targeted switches. Indeed, results of Experiments 2 and 3, across which we
621 varied the switch size and the effectors, indicated that the potentiation effect was only driven
622 by the switch size. It is nevertheless noteworthy that the potentiation effect reported with the
623 small switch seems less clear than the one reported for the large switch. Indeed, this effect
624 failed to reach the corrected statistical significance threshold during planned comparisons.
625 Nevertheless, when we merged data of Experiment 2 and 3 as in our second cross-experiment
626 analysis, it became statistically significant³. In addition, despite the evidence conveyed by
627 each individual experiment, the first cross-experiment analysis suggested that the potentiation

³ Interestingly, the mean size of the potentiation effect (i.e., difference between compatible and non-compatible) was quite similar for both response possibilities (i.e., $m_{\text{large-switch}} = +15$ ms; $s = 24$ vs. $m_{\text{small-switch}} = +14$ ms; $s = 30$) but there was a difference between partial eta squares. More precisely, the partial eta square was larger for the small (i.e., 0.19) than for the large switch (i.e., 0.27). This pattern support that for the small switch compared to the large one, there was a larger variability of the potentiation effect between participants. Indeed, when we took a closer look at the standard deviation, we can see that it was larger for the potentiation effect on the small switch (i.e., 30 ms) compared to the one reported for the large switch (i.e., 24 ms). This increased variability diminished the power of the ANOVA to detect the mean difference. This explains why when we performed separate analysis, the effect failed to reach the statistical significance threshold and that we had to increase the size of the data set to get a statistically significant difference (for a discussion on the difference between standardized and non-standardized size effect, see Baguley, 2009).

628 effect found in Experiment 1 was significantly larger than the one reported in Experiment 2.
629 This difference might suggest that both the switch size and the effector size explained the
630 potentiation effect observed in Experiment 1. Thus, the effector size might only matter when
631 there is also a difference between the sizes of the targeted switches. This hypothesis is
632 consistent with the absence of a statistically significant potentiation effect in Experiment 4
633 where both responses only differed according to the effector size.

634 Nevertheless, because we did not performed an a priori power or precision analysis to
635 determine the sample size ($n = 22$) of our experiments, it is possible to argue that the absence
636 of a statistically significant potentiation effect in Experiment 4 could be due to an
637 underpowered design. To overcome such a limit, we assessed whether our research design
638 could detect our potentiation effect with proper statistical power given our sample size. This
639 power analysis supported that our sample size was reasonably adequate even when we
640 performed highly conservative power analysis (i.e., safeguard; see Perugini, Gallucci, &
641 Costantini, 2014). Altogether, our data supported the idea that the switch size was enough to
642 lead to a size coding of responses. In addition, the size of the used effector part could also
643 matter but seemingly only when the size of switches differed. It is nevertheless noteworthy
644 that such a conclusion about the effector size is only valuable when comparing responses
645 performed with the palm-hand and responses performed with the index-digit. More generally,
646 in experiments reporting a potentiation of grasping behaviors, usually two devices can be used
647 each composed by a large component grasped with a power-grip and a small component
648 grasped with a precision-grip. Thus, one could argue that in these experiments, the size of
649 device parts could favor a size coding of actual responses alternatives resulting in a
650 potentiation effect. Nevertheless, even if our experiments critically support the involvement of
651 the size of switches, it is possible that the size of the used effector parts could also play a role
652 for another kind of responses. For instance, when performing a power-grip, more digits are
653 used and the tactile sensation on the palm-hand is larger than when performing a precision-
654 grip. Such differences at the level of the used effector parts could also take part to the
655 automatic size coding in more classical protocols.

656 Data of Experiment 2 suggested that the potentiation effect reported could be sensitive to
657 the duration of the grayscale prime. Indeed, it only occurred for the shortest SOA (i.e., 200 ms
658 compared with 400 ms and 800 ms). In this experiment, participants had to press the large-
659 switch with their thumb-digit and the small-switch with their index-digit. Our main idea was
660 that SOA might only moderate the size coding based on a difference between switch size, but
661 not the size coding based on a difference between the sizes of effector parts. It could explain
662 why the SOA moderation only occurred in Experiment 2 and not in Experiment 1.
663 Unfortunately, results of Experiment 3 and 4 were not compatible with this view. As in
664 Experiment 2, we only manipulated the size of switches in Experiment 3. Therefore, the SOA
665 should also have moderated the potentiation effect, but it was not the case. Moreover, in
666 Experiment 4, in which we only manipulated the size of effector parts, a potentiation effect
667 should have occurred and should not have been moderated by the SOA. Again, data do not
668 support this prediction because no potentiation effect occurred in this experiment. In addition,
669 the cross-experiment analysis between Experiment 1 and 2 revealed a statistically significant
670 main effect of SOA. More precisely, it seems that the size of the potentiation effect decreased

671 when the SOA became longer. Moreover, the analysis revealed that even if the size of the
672 potentiation effect was statistically significant for the 200 ms- and 400 ms-SOA, it is not the
673 case for the 800 ms-SOA, suggesting a disappearance of the effect for this latter condition.
674 This results partially matched results in the literature supporting that the temporal window of
675 the potentiation effect of grasping behaviors is relatively transient. Indeed, Makris et al.
676 (2011) only observed this effect when the grayscale prime lasted during 400 ms but not during
677 800 ms or 1200 ms, which match the results of our cross-experiment analysis, but did not
678 match the results of our Experiments 1, 2, and 3 taken separately. In one of our recent study,
679 we observed a potentiation effect only for a short SOA (i.e., for 200 ms, but not for 400 ms
680 and 800 ms; Ferrier et al., submitted), which fits the results of our Experiment 2 but not those
681 of our Experiments 1 and 3 or those of our cross-experiment analysis. In sum, these various
682 results seem to suggest that even if the potentiation effect could be transient and moderated by
683 the SOA, it is not enough reliable to clearly observed it with our current protocol. Futures
684 researches should be specifically designed to study this temporal course and particular
685 conditions inducing it especially considering that some studies were able to support the earlier
686 and long-lasting nature of some potentiation effects (e.g. Pellicano, Koch, & Binkofski, 2017;
687 Pellicano & Binkofski, 2020).

688 Our four experiments also exhibited two other results. First, responses were globally
689 affected by the SOA. The longer SOA was, the shorter RTs were. We already reported such a
690 main effect of SOA in previous studies (Ferrier et al., submitted). This link between RTs and
691 SOA is well-known. Indeed, when the foreperiod (i.e., the delay between the warning signal,
692 here the fixation cross, and the reaction signal, here the color change) varies (here, 200, 400,
693 or 800 ms) within a block, the longest RTs are observed after the shortest foreperiod. This
694 pattern perfectly fits our own data. It is assumed that when foreperiods are variable, such a
695 pattern emerges because participants have few reliable information to help them in the proper
696 timing of their preparation (Niemi & Näätänen, 1981). Another result is that there was a
697 difference of RTs between response alternatives. More specifically, in Experiment 1,
698 participants were slower to press the large-switch with their palm-hand than to press the
699 small-switch with their index-digit. Two possible hypotheses can be assumed to explain this
700 result. First, participants might have been slower to press the larger switch for technical
701 reasons (e.g., the switch had longer response latencies). Second, participants might have been
702 slower to perform an action with their palm-hand than with their index-digit. Experiment 2
703 and 3 support the first possibility. Indeed, participants were again longer to press the larger
704 switch compared to the smaller one, independently of the digit used (i.e., index- or thumb-
705 digit). In addition, Experiment 4 supports also the second hypothesis. Indeed, when switches
706 were of a similar size, participants were longer to perform a response with their palm-hand
707 compared to their index-digit. In sum, the difference reported in Experiment 1 is undoubtedly
708 due to the fact that participants were both slower to perform a response with their palm-hand
709 (than with their index-digit) and to press the large switch (than the small one). Nevertheless,
710 this last possibility must be taken cautiously because it deserves a deeper technical
711 investigation of the device.

712 Finally, our data support the view suggesting that the potentiation effect of grasping
713 behaviors could be due to a size coding of manipulable objects and actual responses

714 alternatives (Masson, 2015; Proctor & Miles, 2014). Moreover, such data are particularly
715 interesting because they support the possibility that responses in a two alternative-forced-
716 choice task could be discriminated not only according to their left/right, far/near or up/down
717 dimensions, but also according to the size dimension. This possibility extends the current
718 version of the TEC and adds the size on the list of critical spatial features of actions (see
719 Camus, Hommel, Brunel & Brouillet, 2018 and Coutté, Camus, Heurley & Brouillet, 2017 for
720 converging evidences). To go further, it is noteworthy that our results cannot be taken as a
721 guarantee that the more classical potentiation effect of grasping behaviors (e.g., Ellis &
722 Tucker, 2000) can only be explained by the size-coding-hypothesis. Indeed, it is possible that
723 when participants performed a power- or a precision-grip matching the kind of grips
724 associated with manipulable objects two processes co-exist. First, a process coding the size of
725 manipulable objects and of alternative responses would lead to a potentiation effect based on
726 an representation of the size. Second, another process would be at stake when there is a match
727 between the grasping representations automatically evoked by manipulable objects and the
728 used grip. Indeed, recently, several studies have supported that the potentiation effect
729 observed with manipulable objects with a handle oriented toward the right or left could
730 involve both attentional processes and an automatic access to motor representations (e.g.,
731 Ambrosecchia, Marino, Gawryszewski & Riggio, 2015; Kourtis & Vingerhoets, 2015; Kostov
732 & Janyan, 2012, 2015; Saccone, Churches & Nicholls, 2016). Future researches should be
733 designed to test if it can be also the case for the potentiation of grasping behaviors.

734

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739

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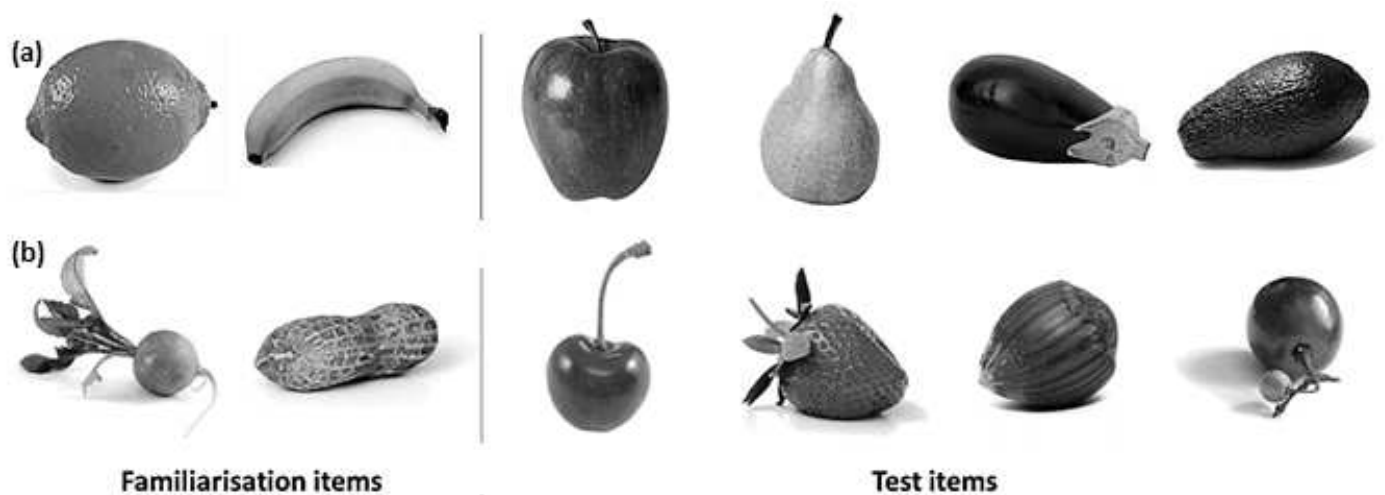
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884

885 **10. Appendix**

886 Large (a) and small (b) objects used in both experimental phases.



887

888 **11. Figure and table captions**

889 **Figure 1** Various kinds of response alternatives and their associated devices used in each
890 experiment (seen from above): (a) Experiment 1, (b) Experiment 2, (c) Experiment 3, and (d)
891 Experiment 4. On each picture, when switches were occulted by the hand, a white transparent
892 square have been added to better understand where switches were located, their size and how
893 participants were instructed to press them.

894

895 **Figure 2** Mean RTs (ms) according to the size of objects (large vs. small), the responses type
896 (varying in each experiment), and experiments: (a) Experiment 1 (palm-hand/large-switch vs.
897 index-digit/small-switch); (b) Experiment 2 (index-digit/small-switch vs. thumb-digit/large-
898 switch); (c) Experiment 3 (index-digit/large-switch vs. thumb-digit/small-switch); and (d)
899 Experiment 4 (palm-hand vs. index-digit).

900

901 **Table 1** Results of performed planned comparisons on RTs (in ms) between conditions where
902 large and small objects were presented for each SOA (200, 400 and 800 ms) and for each
903 response types (thumb-digit/large-switch vs. index-digit/small-switch). We report RTs mean
904 in ms (standard deviation), the F details and if there is a significant or a non-significant effect
905 (S and NS respectively) according to the corrected significance threshold (corrected test-wise
906 $\alpha = .008$ after a Bonferroni correction considering a family of six planned comparisons).

907

908 **Table 2** Results of the regular and safeguard power analyses according to various potential
909 values of the expected effect size. Note. The most plausible scenario and the worst-case
910 scenario according to our current data are highlighted in bold and italic fonts, respectively.

911

912 **12. Footnotes**

913 ¹ It is noteworthy that the ANOVA revealed a statistically significant three-way interaction
914 between the SOA, the response types, and the mapping that is not directly relevant for our
915 main purpose. Indeed, for each mapping and each SOA, difference between RTs reach the
916 significance threshold (all $p < 0.05$) except when the mapping was large-switch-blue and the
917 SOA was 400 ms, $F(1, 20) = 3.35$, $p = .08$, $\eta_p^2 = 0.14$, and when the mapping was small-
918 switch-blue and the SOA was 800 ms, $F(1, 20) = 4.28$, $p = .05$, $\eta_p^2 = 0.18$.

919

920 ² As Cumming (2012, p. 217) reminded P^2 expresses the amount of between-experiment
921 variability (over the total variability) that cannot be explained by random sampling error and
922 reflect actual differences in the effect sizes that could be rather explained by actual
923 differences between research designs.

924

925 ³ Interestingly, the mean size of the potentiation effect (i.e., difference between compatible
926 and non-compatible) was quite similar for both response possibilities (i.e., $m_{\text{large-switch}} = +15$
927 ms; $s = 24$ vs. $m_{\text{small-switch}} = +14$ ms; $s = 30$) but there was a difference between partial eta
928 squares. More precisely, the partial eta square was larger for the small (i.e., 0.19) than for the
929 large switch (i.e., 0.27). This pattern support that for the small switch compared to the large
930 one, there was a larger variability of the potentiation effect between participants. Indeed,
931 when we took a closer look at the standard deviation, we can see that it was larger for the
932 potentiation effect on the small switch (i.e., 30 ms) compared to the one reported for the large
933 switch (i.e., 24 ms). This increased variability diminished the power of the ANOVA to detect
934 the mean difference. This explains why when we performed separate analysis, the effect failed
935 to reach the statistical significance threshold and that we had to increase the size of the data
936 set to get a statistically significant difference (for a discussion on the difference between
937 standardized and non-standardized size effect, see Baguley, 2009).