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## The size coding of responses: The size of switches and the force feedback

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We aimed to understand which factors have a functional role in the size coding of responses, either the size of the switches or the force required to trigger each switch. This question is of relevance because it allows a better understanding of processes underlying action coding. In each trial, participants saw a small or large object. Depending on its colour, the participants had to press one of two switches. In the “size” condition, the response device consisted of two switches of different visual size, but both required the same amount of force. In the “force-feedback” condition, the response device consisted in two switches of identical visual size, but one switch required more force than the other. We found a compatibility effect in the “size,” not in the “force-feedback” condition, supporting that the size-coding of responses would be due to the size of the switches.

**Keywords:** Action coding; Stimulus–response compatibility effect; Size; Grasable objects; Force feedback.

How people represent their body in action remains a critical issue in Cognitive Sciences. A fruitful line of inquiry consists in using Stimulus–Response Compatibility (SRC) effects like the Simon effect (Simon & Rudell, 1967). Multiple studies supported that responses can be coded thanks to their spatial features along the left–right, proximal–distal or up–down axis (for a review, see Proctor & Vu, 2006). We recently reported the possibility that participants code their responses along the size dimension (Guerineau et al., 2021; Harrak et al., 2022; Heurley et al., 2020). Specifically, in Heurley et al. (2020) experiment, participants saw small or large objects in grayscale which rapidly turned blue or orange. According to the colour, participants were instructed to press either a small or a large switch. Results exhibit shorter response times when the object and the response sizes match rather than mismatch. In the current article, our goal was to better understand which responses’ features allow this size

coding and beyond, the neurocognitive processes possibly recruited.

Heurley et al. (2020) ran three additional experiments supporting that the size-coding of responses would mainly rely on the switches’ size instead of the size of the effector involved. Precisely, they did not find a size-based SRC effect when participants had to use their forefinger and palm hand to press two switches of the exact same size (for converging results with the Simon task, see Buhlmann et al., 2007). However, this size coding of responses may also rely on another, confounded, factor: the force feedback. Indeed, in this study, switches differed not only in their size but also according to the force required to trigger a response. More precisely, less force was required to activate the small switch compared with the large one. Accordingly, it is possible that the size coding depended on the force associated to each switch rather than on their size. Indirect evidence supporting

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All authors conceived the theoretical rationale of the studies and designed the two studies. Loïc P. Heurley and Guillaume Thébault conducted Experiment 1 and 2 respectively. Loïc P. Heurley conducted the data analyses. All authors drafted the manuscript and approved the final version of the manuscript for submission.

this possibility comes from studies showing force-based SRC effects. For instance, in Mattes et al. (2002, Experiment 5), participants had to perform either a forceful or weak keypress based on the shape of dim or bright stimuli (i.e., circle vs. diamond). Forceful keypresses were faster for the brighter stimuli and weak keypresses for the dimmer ones. Similarly, Vierck and Kiesel (2010) reported faster forceful keypress when large rather than small numbers were processed, and the reverse for weak responses. Thus, for Heurley et al. (2020), we can imagine a similar effect because of the objects visual size: the large objects may favour forceful responses compared with a weak response, and conversely for small objects. Moreover, the potential involvement of force feedback is reinforced by the possibility that the size coding of response can be imputable to the magnitude of responses' feedback (Guerineau et al., 2021). Additionally, the relevance of force feedback into action coding is in accordance with studies reporting the involvement of this kind of feedback in action planning and action control (e.g., Michalland et al., 2019; Saint-Aubert et al., 2019; Thébault et al., 2018, 2020).

Accordingly, we aim to investigate whether the size coding of responses relies on the switches size, the force required to press each switch (i.e., force feedback), or both effects. Based on Heurley et al. (2020) procedure, we ran an experiment with two conditions. In each trial, participants saw a small or large object in grayscale, which then turned blue or orange. Depending on the colour, participants had to press a switch among two. In the "size" condition, the response device was a small and a large switch requiring the same amount of force to be activated. In the "force" condition, the response device was two switches of identical visual size, but one switch required more force than the other to be triggered. Based on the reviewed literature, we predicted an Object Size  $\times$  Response interaction in both conditions. Namely, we expected faster RTs when the objects size was compatible either with the switch size (i.e., the size condition), or with the force required to trigger the switch (i.e., the force condition).

## METHOD

### Participants

To determine an appropriate sample size to detect the Object Size  $\times$  Response interaction, we conducted an a priori power analysis using G\*Power 3 (Faul et al., 2007), using the  $F$  test family and "ANOVA repeated measures, within factors" as statistical test. The result indicated that a minimum of 24 participants was required to detect an effect size as large as  $\eta_p^2 = 0.21$  in a within-subject design with 95% statistical power ( $\alpha = 0.05$ ). We selected this effect size because Heurley et al. (2020) reported an

effect size of  $\eta_p^2 = 0.37$  for the Object Size  $\times$  Response interaction in their between-experiments analysis. To prevent a potential overestimation of the effect in their analysis, we used the lower limit of the 80% CI for  $\eta_p^2$  [0.21, 0.48] of their effect as a safeguard (see Perugini et al., 2014).

Accordingly, 24 students performed the "size" condition: 12 females and 12 males ( $m_{\text{age}} = 24.3$ ,  $s_{\text{age}} = 3.1$ ) including 7 left-handed. Similarly, 24 students performed the "force" condition: 17 females and 7 males ( $m_{\text{age}} = 23.2$ ,  $s_{\text{age}} = 4.6$ ) including 5 left-handed. All reported a normal or corrected-to-normal visual acuity, and no colour perception issues (e.g., colour-blindness). This study followed the ethical principles of the American Psychological Association (2017). Participants were volunteers, provided their written informed consent to participate without remuneration, and were debriefed at the end of the experiment.

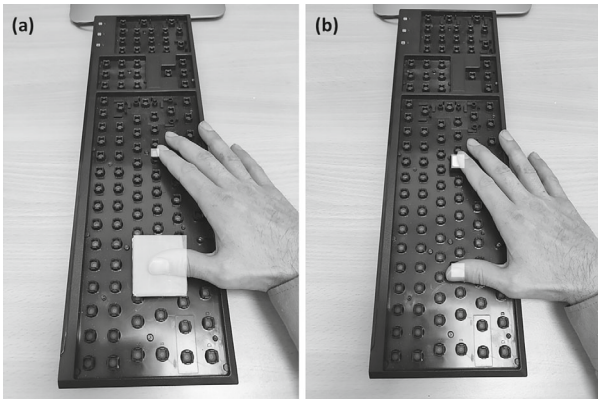
### Material

As in Heurley et al. (2020), we used the same 12 pictures of fruits and vegetables: six pictures of large fruits or vegetables usually grasped with a power-grip and six of small fruits or vegetables usually grasped with a precision-grip (see Figure A1). All pictures were presented against a white background in a visual size matching the actual size of the depicted fruits and vegetables (large objects  $\approx 10^\circ$  of visual angle and small objects  $\approx 3^\circ$ ). We designed three versions of each picture (grayscale, blue and orange).

We also used two response devices. For the "size" condition, the device was an AZERTY keyboard whose alphanumeric keys were removed except the "D" and "L" keys. We constructed two switches: the small switch was a usual keyboard key that was cut to measure 0.5 cm  $\times$  0.5 cm, while we fixed a plastic component measuring 5 cm  $\times$  4 cm on a usual keyboard key to obtain the large switch (see Figure 1a). For the "force" condition, the device was a similar AZERTY keyboard whose alphanumeric keys were also removed except the "D" and "L" keys. To properly control the switches' size, we took two usual keyboard keys measuring 1.5 cm  $\times$  1.5 cm. To increase the force required to press the forceful switch, we added a small spring under the corresponding key ensuring that the force required is always larger than the amount of force required to press the other response for which there is no spring (see Figure 1b).

### Procedure

Each participant was individually tested in a quiet room where they were seated in front of a monitor (23"; refresh rate: 60 Hz; resolution: 1980  $\times$  1080 pixels; placed at 60 cm). The experiment began with a two-step preliminary phase. In the first, the 12 pictures were presented successively with their name written below, and



**Figure 1.** The response devices used for (a) the “size” condition, and (b) for the “force” condition. White transparent squares have been added to better understand where switches were located, their size and how participants were instructed to press them.

participants had simply to read aloud the name of each item. The second step was similar except the names were no longer presented (see Bub et al., 2008, for a similar preparation).

For each familiarisation and test trials, a fixation cross was first displayed at the centre of the screen (500 ms). A picture of a fruit or vegetable then appeared in grayscale during 200, 400 or 800 ms (Stimulus Onset Asynchrony [SOA], as in Heurley et al., 2020) before turning blue or orange. The task was to categorise the colour as quickly and accurately as possible. The response was followed by a blank screen during 2500 ms. In both conditions, participants had to press one of the switches with their thumb and the other with their index finger (Figure 1). We choose these two fingers based on Heurley et al. (2020, Experiment 2 and 3) who did not find any influence of these effectors in the size coding of responses. To properly counterbalance the switches’ feature (i.e., the visual size in the “size” condition and the force in the “force” condition), their location (near vs. far), and their associated colour (blue vs. orange), participants were randomly assigned into one of the four mapping groups in each experiment.

In both conditions, instructions never depicted the switches according to their size or to the force required to press them. Switches were solely described according to their associated colour (i.e., blue or orange switch). In addition, the response device was put in front of the participants along their body midline (Figure 1) to avoid a possible response coding along the left–right axis, which is known to induce a Simon effect (Simon & Rudell, 1967). Participants responded with their dominant hand. The “size” condition was run on an HP-Probook-650G1 2.40 GHz computer while the “force” condition was run on a Toshiba Satellite Pro L670 2.27 GHz and both experiments were controlled thanks to OpenSesame 3.3.9 (Mathôt et al., 2012). In both

conditions, there were 24 familiarisation trials followed by 192 test trials (8 fruits/vegetables  $\times$  2 repetitions  $\times$  2 colours  $\times$  3 SOA  $\times$  2 blocks).

Finally, participants completed the 4-items version of the Edinburgh Handedness Inventory (Veale, 2013) and a short questionnaire to gather complementary information.

## RESULTS

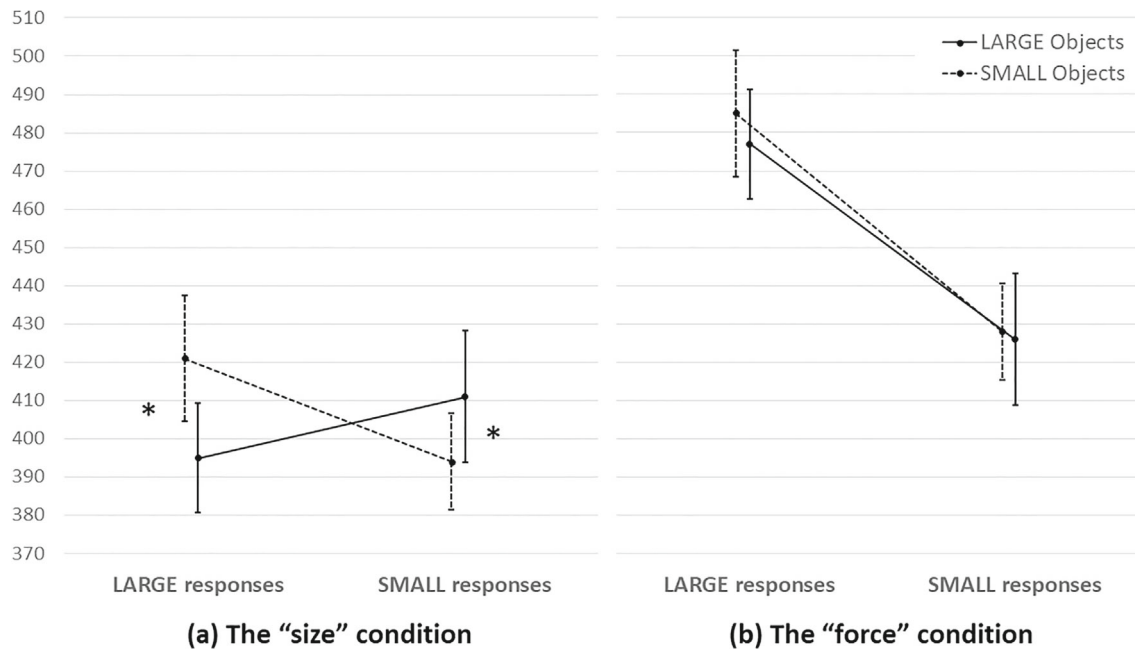
In both conditions, we only analysed RTs given the small number of errors to analyse accuracy (i.e., 4.1 and 1.0% for the “size” and “force” condition, respectively). Following Heurley et al. (2020), we removed familiarisation trials and incorrect test trials, as well as trials in which RTs were below 200 ms or above 1200 ms (0.2 and 0.4% for the “size” and “force” condition, respectively). We ran repeated-measures ANOVA in both conditions with participants as a random variable, response type (the “size” condition: large vs. small and the “force” condition: hard vs. soft) and object size (large vs. small) as fixed within-participants independent variables. In addition, we performed a between-conditions analysis as well as an analysis including the SOA.

### The “size” condition

The ANOVA did not reveal a main effect of the response type,  $F(1, 23) = 1.41, p = .25, \hat{\eta}_p^2 = 0.06$ , and of the object size,  $F(1, 23) = 2.44, p = .13, \hat{\eta}_p^2 = 0.10$ . The ANOVA revealed a significant Response Type  $\times$  Object Size interaction,  $F(1, 23) = 27.36, p < .001, \hat{\eta}_p^2 = 0.54$  (see Figure 2a). Based on the corrected significance threshold (corrected test-wise  $\alpha = 0.025$  after a Bonferroni correction considering a family of two comparisons), planned comparisons showed that large-switch RTs were shorter for large objects ( $m = 394$  ms;  $s = 36$ ) than for small ones ( $m = 422$  ms;  $s = 41$ ),  $F(1, 23) = 24.27, p < .001, \hat{\eta}_p^2 = 0.51$ , and small-switch RTs were shorter for small objects ( $m = 394$  ms;  $s = 32$ ) than for large ones ( $m = 411$  ms;  $s = 43$ ),  $F(1, 23) = 10.76, p = .003, \hat{\eta}_p^2 = 0.32$ .

### The “force” condition

The ANOVA revealed a main effect of the response type with shorter RTs for the soft responses ( $m = 427$  ms;  $s = 53$ ) than for the hard ones ( $m = 481$  ms;  $s = 59$ ),  $F(1, 23) = 90.31, p < .001, \hat{\eta}_p^2 = 0.80$ . This effect is trivially attributable to greater difficulty to activate the hard switch. The ANOVA neither revealed a main effect of the object size,  $F(1, 23) = 2.66, p = .12, \hat{\eta}_p^2 = 0.10$ , nor of the Response Type  $\times$  Object Size interaction,  $F(1, 23) = 0.69, p = .41, \hat{\eta}_p^2 = 0.03$  (see Figure 2b).



**Figure 2.** Response times according to the object size (large vs. small) as well as to the response type (the “size” condition: large vs. small; the “force” condition: hard vs. soft) for the “size” condition (a) and for the “force” condition (b). Error bars represent correlation- and difference-adjusted 95% confidence intervals for the means calculated with WSPLOT for SPSS (O’Brien & Cousineau, 2014; for a standard terminology for SE and CI, see Cousineau, 2017). Statistically significant differences are indicated by asterisks.

### Between-conditions analysis

We ran an additional mixed ANOVA with participants as a random variable, response type (the “size” condition: large vs. small and the “force” condition: hard vs. soft) and object size (large vs. small) as fixed within-participants independent variables and the condition (size vs. force condition) as a fixed between-participants independent variable. The major result was the significant Condition  $\times$  Response Type  $\times$  Object Size interaction,  $F(1, 46) = 11.68$ ,  $p = .001$ ,  $\hat{\eta}_p^2 = 0.20$  supporting the relevance of our previous separate analyses.

### The SOA analysis for the “size” condition

Indeed, some studies advocated the possibility that the congruity effects occur in a peculiar temporal window usually comprised between 200 and 800 ms (García & Ibáñez, 2016; Heurley et al., 2020; Makris et al., 2011). Because in the “size” condition, we find a compatibility effect and because we manipulated the SOA, we want to test whether the compatibility effect can be modulated by the SOA. Accordingly, we ran a last mixed ANOVA with participants as a random variable, response type (large vs. small), object size (large vs. small) and SOA (200 ms vs. 400 vs. 800 ms) as fixed within-participants independent variables. The ANOVA revealed a significant SOA  $\times$  Response Type  $\times$  Object Size interaction,  $F(2, 23) = 6.06$ ,

$p = .005$ ,  $\hat{\eta}_p^2 = 0.21$ . More precisely, planned comparisons revealed that the Response Type  $\times$  Object Size interaction was significant at a 200 ms-SOA,  $F(1, 23) = 30.14$ ,  $p < .001$ ,  $\hat{\eta}_p^2 = 0.57$ , as well as at a 400 ms-SOA,  $F(1, 23) = 21.77$ ,  $p < .001$ ,  $\hat{\eta}_p^2 = 0.49$ , but it was no longer significant at 800 ms-SOA,  $F(1, 23) = 2.38$ ,  $p = .14$ ,  $\hat{\eta}_p^2 = 0.09$ .

Further details about this last analysis as well as an additional analysis including the blocs are available in Data S1. All pictures, OpenSesame scripts, raw data and analyses are available online (<https://osf.io/cg6m9/>).

## DISCUSSION

In their study, Heurley et al. (2020) found that large and small stimuli can facilitate keypress responses performed on large and small switches respectively, supporting a possible response coding along the size dimension (see also Guerineau et al., 2021). However, because the switches’ size was confounded with the force required to respond, it was difficult to conclude whether the size coding of responses was due to the switches size and/or the force involved to trigger it. Such issue is of primary relevance to elucidate which processes promote body and action representation. Accordingly, in our current study, we designed an experimental protocol as close as possible to the one of Heurley et al. (2020), but able to properly disentangle the influence of both factors. We gathered



various results leading to several contributions that are discussed below.

First of all, we found a compatibility effect in the “size” condition but not in the “force” one. This result suggests that the size coding of responses originally reported by Heurley et al. (2020) can be attributable to the switches’ size rather than to the force required by each switch. Two additional results also supported this conclusion. First, the magnitude of the compatibility effect found in the “size” condition (i.e., +22 ms) is close to the one reported by Heurley et al. (2020; +15 ms). Second, as in Heurley et al. (2020), this effect is modulated by the SOA: the compatibility effect decreases as the SOA increases. Overall, these results suggested a consistency between our current results and those of Heurley et al. (2020). In addition, Heurley et al. (2020) found a compatibility effect for the large and small switch, but with longer overall RTs for the large switch than for the small one. They hypothesized that this main effect occurred because the large switch was harder to trigger (i.e., requiring more force). We found a similar pattern in the “force” condition but not in the “size” condition: the hard switch produced longer RTs than the soft one. Finally, it is noteworthy that despite the main effect of switches, Heurley et al. (2020) were able to find a compatibility effect. It is therefore unlikely that a possible compatibility effect in the “force” condition of the present experiment was hidden by the main effect of responses (e.g., a ceiling effect).

One critical question is why the size coding of responses predominantly depends on the size of the switches rather than on the force required to trigger each switch (i.e., force feedback). This question is particularly intriguing considering that various works already reported force-based SRC effects (e.g., Mattes et al., 2002). One possible explanation may rely on the kind of task used in these experiments. Indeed, researchers explicitly asked participants to adjust the force of their response according to a feature of the stimulus. For instance, when the shape was a circle, the participants have to press forcefully while when it was a diamond, they have to press slightly. Thus, participants should intentionally control the amount of force deployed. This hypothesis is in line with studies showing that the coding of responses mainly depends on intentional processes increasing the relevance of some response’s components (e.g., Guiard, 1983; Hommel, 1993). Instead, in our own experiment, participants just had to adapt the force deployed according to the hardness of each switch, which may account for the fact that we did not find any force-based SRC effect.

Lastly, our study contributes to a better understanding of the congruity effect of grasping behaviours (Ellis & Tucker, 2000) and more specifically, supports the size coding account of the effect (Proctor & Miles, 2014). Indeed, in our work, the chosen stimuli are objects usually grasped by a power or precision grip in daily life (e.g., an apple vs. a cherry). In line with Heurley et al. (2020),

we reported that this kind of objects was able to facilitate mere keypress responses that can be coded as large and small. As already advocated, this suggests that the mainstream motor simulation account of the congruity effect of grasping behaviours (e.g., Barsalou, 2008; Ellis, 2007) should be taken cautiously (e.g., Heurley et al., 2020). Our current results allow us to go further and to support the possibility that the congruity effect of grasping behaviours could rely on the switches size rather than on the force associated to each grip. Future studies on the congruity effect of grasping behaviours, especially those designed to test the motor simulation account of this effect, should properly control the switches’ size and/or should add a control condition to overcome a size-coding interpretation.

## ETHICS STATEMENT

This study was in accordance with the ethical principles of the American Psychological Association (APA, 2017), with the ethical standards as laid down in the 1964 Declaration of Helsinki and its later amendments and with the laws of the country (France) in which the study has been achieved.

## INFORMED CONSENT

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

## OPEN PRACTICES STATEMENT

Raw data, analyses, OpenSesame scripts and material are available on the Open Science Framework (<https://osf.io/cg6m9/>).

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## SUPPORTING INFORMATION

Additional supporting information may be found online in the Supporting Information section at the end of the article.

**Data S1.** Supporting Information.

## REFERENCES

- American Psychological Association. (2017). *Ethical principles of psychologists and code of conduct*. American Psychological Association.
- Barsalou, L. W. (2008). Grounded cognition. *Annual Review of Psychology*, 59(1), 617–645. <https://doi.org/10.1146/annurev.psych.59.103006.093639>

- Bub, D. N., Masson, M. E. J., & Cree, G. S. (2008). Evocation of functional and volumetric gestural knowledge by objects and words. *Cognition*, *106*(1), 27–58. <https://doi.org/10.1016/j.cognition.2006.12.010>
- Buhlmann, I., Umiltà, C., & Wascher, E. (2007). Response coding and visuomotor transformation in the Simon task: The role of action goals. *Journal of Experimental Psychology: Human Perception and Performance*, *33*(6), 1269–1282.
- Cousineau, D. (2017). Varieties of confidence intervals. *Advances in Cognitive Psychology*, *13*(2), 140–155. <https://doi.org/10.5709/acp-0214-z>
- Ellis, R. (2007). Grounding visual object representation in action. In B. Wallace, A. Ross, J. Davies, & T. Anderson (Eds.), *The mind, the body and the world: Psychology after cognitivism?* (pp. 309–326). Exeter.
- Ellis, R., & Tucker, M. (2000). Micro-affordance: The potentiation of components of action by seen objects. *British Journal of Psychology*, *91*(4), 451–471.
- Faul, F., Erdfelder, E., Lang, A.-G., & Buchner, A. (2007). G\*power 3: A flexible statistical power analysis program for the social, behavioral, and biomedical sciences. *Behavior Research Methods*, *39*(2), 175–191. <https://doi.org/10.3758/BF03193146>
- García, A. M., & Ibáñez, A. (2016). A touch with words: Dynamic synergies between manual actions and language. *Neuroscience & Biobehavioral Reviews*, *68*, 59–95. <https://doi.org/10.1016/j.neubiorev.2016.04.022>
- Guerineau, R., Heurley, L. P., Morgado, N., Brouillet, D., & Dru, V. (2021). Anticipating the magnitude of response outcomes can induce a potentiation effect for manipulable objects. *Psychological Research*, *86*, 667–684. <https://doi.org/10.1007/s00426-021-01535-0>
- Guiard, Y. (1983). The lateral coding of rotations: A study of the Simon effect with wheel-rotation responses. *Journal of Motor Behavior*, *15*(4), 331–342.
- Harrak, M. H., Heurley, L. P., Morgado, N., Mennella, R., & Dru, V. (2022). The visual size of graspable objects is needed to induce the potentiation of grasping behaviors even with verbal stimuli. *Psychological Research*, *1-16*, 2067–2082. <https://doi.org/10.1007/s00426-021-01635-x>
- Heurley, L. P., Brouillet, T., Coutté, A., & Morgado, N. (2020). Size coding of alternative responses is sufficient to induce a potentiation effect with manipulable objects. *Cognition*, *205*, 104377. <https://doi.org/10.1016/j.cognition.2020.104377>
- Hommel, B. (1993). Inverting the Simon effect by intention. *Psychological Research*, *55*(4), 270–279. <https://doi.org/10.1007/BF00419687>
- Makris, S., Hadar, A. A., & Yarrow, K. (2011). Viewing objects and planning actions: On the potentiation of grasping behaviours by visual objects. *Brain and Cognition*, *77*(2), 257–264. <https://doi.org/10.1016/j.bandc.2011.08.002>
- Mathôt, S., Schreij, D., & Theeuwes, J. (2012). OpenSesame: An open-source, graphical experiment builder for the social sciences. *Behavior Research Methods*, *44*(2), 314–324. <https://doi.org/10.3758/s13428-011-0168-7>
- Mattes, S., Leuthold, H., & Ulrich, R. (2002). Stimulus-response compatibility in intensity-force relations. *The Quarterly Journal of Experimental Psychology: Section A*, *55*(4), 1175–1191. <https://doi.org/10.1080/02724980244000152>
- Michalland, A. H., Thébault, G., Briglia, J., Fraisse, P., & Brouillet, D. (2019). Grasping a Chestnut Burr. *Experimental Psychology*, *66*, 310–317. <https://doi.org/10.1027/1618-3169/a000449>
- O'Brien, F., & Cousineau, D. (2014). Representing error bars in within-subject designs in typical software packages. *The Quantitative Methods for Psychology*, *10*(1), 56–67. <https://doi.org/10.20982/tqmp.10.1.p056>
- Perugini, M., Gallucci, M., & Costantini, G. (2014). Safeguard power as a protection against imprecise power estimates. *Perspectives on Psychological Science*, *9*(3), 319–332. <https://doi.org/10.1177/1745691614528519>
- Proctor, R. W., & Miles, J. D. (2014). Does the concept of affordance add anything to explanations of stimulus–response compatibility effects? In K. D. Federmeier (Ed.), *Psychology of learning and motivation* (Vol. 60, pp. 227–266). Academic Press.
- Proctor, R. W., & Vu, K. P. L. (2006). *Stimulus-response compatibility principles: Data, theory, and application*. CRC Press.
- Saint-Aubert, J., Heurley, L. P., Morgado, N., Régnier, S., & Haliyo, S. (2019). Pre-calibrated visuo-haptic co-location improves execution in virtual environments. *IEEE Transactions on Haptics*, *13*(3), 588–599. <https://doi.org/10.1109/TOH.2019.2957801>
- Simon, J. R., & Rudell, A. P. (1967). Auditory SR compatibility: The effect of an irrelevant cue on information processing. *Journal of Applied Psychology*, *51*(3), 300–304. <https://doi.org/10.1037/h0020586>
- Thébault, G., Michalland, A. H., Derozier, V., Chabrier, S., & Brouillet, D. (2018). When the vibrations allow for anticipating the force to be produced: An extend to Pfister et al. (2014). *Experimental Brain Research*, *236*(4), 1219–1223. <https://doi.org/10.1007/s00221-018-5190-x>
- Thébault, G., Pfister, R., Michalland, A. H., & Brouillet, D. (2020). Flexible weighting of body-related effects in action production. *Quarterly Journal of Experimental Psychology*, *73*(9), 1360–1367. <https://doi.org/10.1177/1747021820911793>
- Veale, J. F. (2013). Edinburgh handedness inventory – short form: A revised version based on confirmatory factor analysis. *Laterality: Asymmetries of Body, Brain and Cognition*, *19*(2), 164–177. <https://doi.org/10.1080/1357650X.2013.783045>
- Vierck, E., & Kiesel, A. (2010). Congruency effects between number magnitude and response force. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *36*(1), 204–209. <https://doi.org/10.1037/a0018105>

APPENDIX

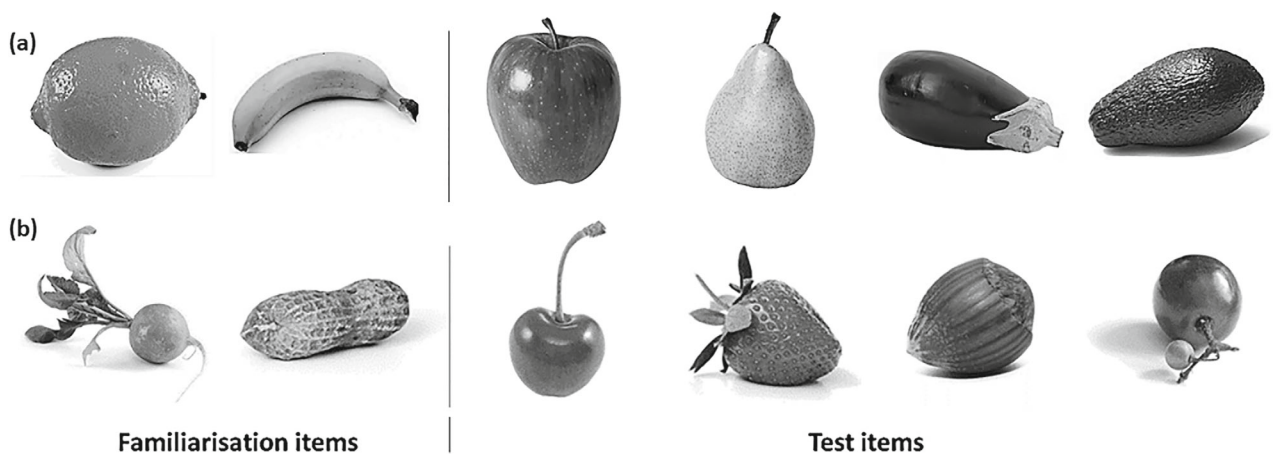


Figure A1. (a,b) Pictures of objects used with (1) the phase in which they were used (familiarisation or test) and (2) the size associated.