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SPECIFICITY OF INHIBITION IN ATTENTION TO NUMBER

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Attention to Number requires magnitude-specific inhibition

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25 **Attention to Number requires magnitude-specific inhibition**

26

27 **Abstract**

28 Recent studies have shown that the ability to process number in the face of conflicting dimensions of
29 magnitude is a crucial aspect of numerosity judgments, relying in part on the inhibition of the non-
30 numerical dimensions. Here we report, for the first time, that these inhibitory control processes are
31 specific to the conflicting dimension of magnitude. Using a non-symbolic numerical comparison task
32 adapted to a conflict adaptation paradigm on a group of 82 adults, we show that congruency effects
33 between numerical and non-numerical information were reduced only when the conflicting
34 dimension was the same in the preceding incongruent trial. Attention to number thus involves
35 inhibitory control processes acting at a specific level of information. These results contribute to
36 better characterize the domain general abilities involved in numerical cognition, and provide
37 evidence for a specific interaction between numerosity perception and inhibitory control.

38 **Keywords**

39 Numerical cognition; numerical estimation; Inhibitory control; conflict adaptation

40

41 **1. Introduction**

42 One of the main objects of investigation in the field of numerical cognition in the past decades has
43 been our number sense, that is our ability to estimate and compare the quantities of objects in a set
44 (“numerosities”, Izard et al., 2009; Feigenson et al., 2004). Classically, the non-symbolic numerical
45 comparison task is used to assess the precision of our number sense. In this task, the participants are
46 asked to decide which of two rapidly presented sets of items (usually dots) is the more numerous.
47 Because of the perceptual features of the sets of dots presented in the non-symbolic numerical
48 comparison task, many studies have called into question its underlying mechanisms. Recently indeed,

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49 beyond the precision of our number sense, studies have suggested that the non-symbolic numerical
50 comparison task also relies on the ability to process numerosities independently of competing
51 dimensions of magnitude, such as size, density, or occupied space (hereafter referred to as
52 “attention to number”, Wilkey & Price, 2019; see also Piazza et al., 2019). This stems in part from the
53 systematic observation that the non-numerical dimensions of magnitude present in the stimuli,
54 impact our performance in the task (Gebuis & Reynvoet, 2012; 2013).

55 One of the proposed mechanisms of attention to number is inhibitory control, which allows blocking
56 the irrelevant, non-numerical dimensions of magnitude when processing numerosities (Fuhs &
57 McNeil, 2013; Fuhs et al., 2016; Rousselle & Noël, 2008; Szűcs et al., 2013). Recently, using a non-
58 symbolic numerical comparison task adapted to a negative priming paradigm, Viarouge and
59 colleagues (2019) provided evidence for the role of inhibitory control during the numerical
60 comparison of two arrays of dots whereby number was incongruent with dots’ size.

61 While inhibition seems to play a role when performing numerosity judgment tasks, studies are
62 needed to better characterize the inhibitory control processes at play in this context. In particular,
63 one opened question is the degree of specificity of the inhibitory control processes involved in
64 attention to number. On one hand, one could postulate the existence of a common mechanism
65 aimed at blocking any conflicting information of magnitude when processing numerosities. On the
66 other hand, the inhibitory control processes at play when attending to number could be specific to
67 the irrelevant dimension of magnitude conflicting with number.

68 One way to disentangle these hypotheses is by studying the congruency sequence effect, or Gratton
69 effect (Gratton, Coles, & Donchin, 1992), consisting of a reduced congruency effect following
70 incongruent trials. This effect has previously been observed in several classic inhibitory control tasks,
71 such as the Stroop or the Flanker task (Hommel, Proctor, & Vu, 2004; Larson, Kaufman, & Perlstein,
72 2009). It is most commonly explained by the conflict adaptation account (Botvinick et al., 2001),

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73 which states that the cognitive control processes - including the inhibition of irrelevant information -
74 involved in solving an incongruent trial facilitate the resolution of the next conflict.

75 Using such conflict adaptation paradigm, several studies have investigated the specificity of cognitive
76 control processes in the context of numerical tasks, with mixed results. Some studies have concluded
77 to a general inhibitory control process (Borst, Poirel, Pineau, Cassotti and Houdé, 2012; Linzarini et
78 al., 2015). For instance, using an inter-task conflict adaptation paradigm, Linzarini and colleagues
79 (2015) observed that 9-year-olds performed better in the incongruent trials of a Piaget-like number
80 conservation task (two rows of tokens with either identical numbers and different lengths, or
81 different numbers and equal lengths) when they were preceded by incongruent Stroop trials. The
82 authors concluded that their results supported a general inhibitory control process across both tasks
83 in 9-year-old children. In their study however, Notebaert and Verguts (2008) observed a congruency
84 sequence effect in a group of adults across two tasks (a Simon task using on laterally presented X's
85 and a SNARC task on centrally presented symbolic digits) only when the relevant information was the
86 same in both tasks, leading the authors to conclude for more specific cognitive control abilities. Since
87 the irrelevant information remained identical throughout their study, the authors argued that their
88 results showed the specificity of the processing of the relevant information, rather than of the
89 inhibition of the irrelevant information. To date, no study has investigated this question in the
90 context of a non-symbolic numerical task, with a constant relevant information (i.e. numerosity) and
91 a varying irrelevant information (i.e. conflicting dimensions of magnitude).

92 Thus, in the current study, we adapted a non-symbolic comparison task to a conflict adaptation
93 paradigm, using different non-numerical dimensions of magnitude, in order to investigate whether
94 the inhibitory control processes at play were specific to the irrelevant information, or general across
95 the non-numerical dimensions of magnitude. We reasoned that, if attention to number requires
96 dimension-general inhibition, then we should observe cross-dimension Gratton effects, i.e. reduced
97 congruency effects in trials preceded by incongruent trials, regardless of the irrelevant dimension of

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98 magnitude conflicting with number. On the other hand, if the inhibitory control processes involved in
99 attention to number are dimension-specific, we should only observe within-dimension Gratton
100 effects, i.e. reduced congruency effects following incongruent trials involving the same irrelevant
101 non-numerical dimension of magnitude.

102 2. Method

103 2.1. Participants

104 Participants were 82 undergraduate students at Université de Paris (4 males, mean age = 21 years,
105 SD = 4.8), participating in the study for course credit.

106 The ethical board of the Faculty of Psychology ruled that in light of the potential risks for the
107 participants of the present study, no formal ethical approval by one of the national ethical
108 committee was needed in agreement with the Ethical law governing human research in France.
109 Participation was voluntary after obtaining signed informed consent. All participants were tested in
110 accordance with national and international norms governing the use of human research participants.

111 2.2. Procedure

112 The task consisted in a non-symbolic numerical comparison task adapted to a conflict monitoring
113 paradigm. Participants were asked to indicate as quickly and as accurately as possible which of two
114 arrays of dots, presented on the left and right side of a computer screen, contained more dots, by
115 pressing either the D (left array) or the K (right array) key on the keyboard. The task was
116 programmed using the jsPsych JavaScript library (de Leeuw, 2015), and the data collected online on
117 the Cognition.run platform. Each presentation of a pair of dot arrays will thereafter be referred to as
118 an item. A trial was defined as a sequence of two items, a prime item followed by a probe item
119 (Figure 1).

120 In order to adapt the non-symbolic numerical comparison task to a negative priming paradigm, two
121 non-numerical dimensions needed to be manipulated orthogonally, on a trial-by-trial basis. That is,

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122 the congruency of one dimension relative to number needed to be manipulated, at the trial level,
123 independently of a third dimension.

124 Such manipulation at the trial level would prove difficult using dimensions such as average item size
125 and total surface area, which are, by definition, correlated. This is why the arrays of dots were
126 generated with MATLAB using the *Number, Size, and Spacing* dimensions, as defined by DeWind and
127 colleagues (2015), which form an orthogonal space whereby the three dimensions can be
128 manipulated independently. That is, we manipulated a combination of aspects of average item size
129 and total surface area on one hand (the *Size* dimension), and a combination of convex hull and
130 density (the *Spacing* dimension) on the other. By doing so, for each item (prime or probe), one non-
131 numerical dimension of magnitude was either congruent or incongruent with Number (thereafter
132 referred to as the “congruency-related dimension”), while the other was constant across the two
133 arrays. Hence, the congruency-related dimension (e.g. *Size*) and its composing magnitudes (e.g.
134 average item size and total surface area) are the only changing parameters between our conditions,
135 at a trial-by-trial level (see Appendix A, Table A1, for a table showing the congruency and ratios of the
136 four composing magnitudes in each condition, and Figures A1 and A2 for examples of stimuli in
137 relation to our results). This led to four types of items depending on the congruency-related
138 dimension (*Size* or *Spacing*), and its congruency with Number (congruent or incongruent). All possible
139 combinations of the four types of items were presented, leading to 16 different trial conditions (i.e.
140 prime-probe pairs). Consequently, for half of those 16 trial conditions, the congruency-related
141 dimension was identical in the prime and in the probe items (“within-dimension trials”), while for the
142 other half the congruency-related dimension was different between the prime and the probe
143 (“between-dimension trials”). Each of the 16 trial conditions was presented 10 times in a random
144 order, for a total of 160 trials.

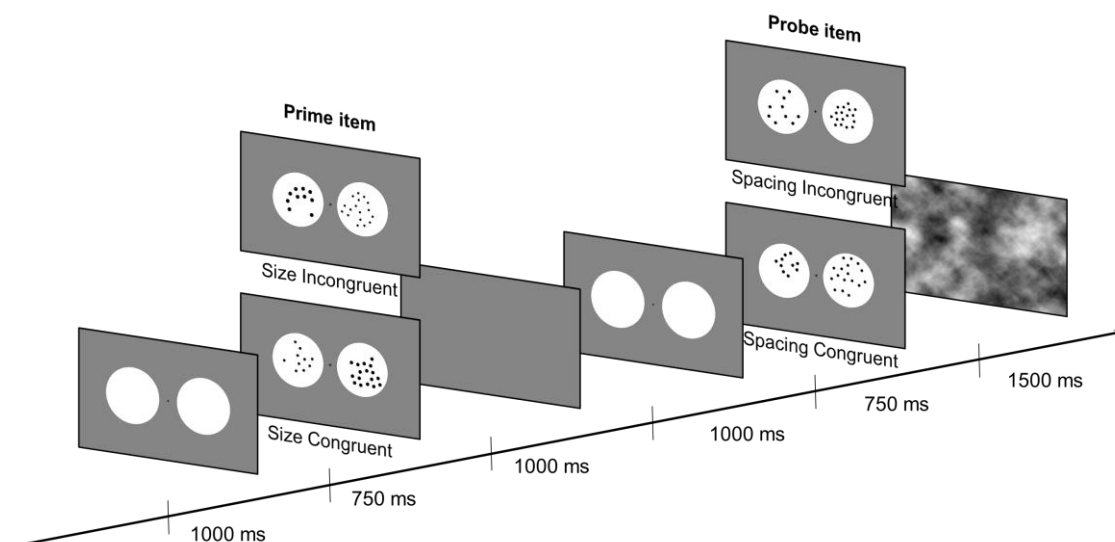
145 Each trial started with a central fixation cross and two white circles (1000ms). The arrays of dots from
146 the prime item were then presented in the white circles until the participants gave a response, for a

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147 maximum duration of 750ms, at which time they were replaced by a gray screen. As soon as the
148 participants gave their response to the prime, a gray screen was presented for 1000ms, and then the
149 fixation cross and the probe were presented. In order to separate the trials and minimize the
150 potential effect of probes on the following primes (Linzarini et al., 2015), a visual mask was presented
151 for 1500ms between each prime-probe pair.

152 Using the jsPsych calibration plugin, the stimuli were set to be presented at a fixed size of 14.7x11cm
153 on the participants' screen. Using these settings, each array of black dots was presented on a white
154 circle with 6.71cm diameter (visual angle 7.64° for a distance of 50cm from the screen). The center of
155 the arrays of dots was at 4.14cm from the central fixation cross (visual angle 4.73°). In order to
156 ensure a high enough level of performance for the analyses of the priming effects on the probe
157 items' reaction times, all the items presented a numerical ratio of approximately 3:5. Different
158 number pairs were presented (9-15, 10-17, 12-20, 14-23), so as to avoid recognition of the
159 numerosities throughout the task. The ratio of the congruency-related dimension was always set at a
160 third (with a 10% margin of error for the Spacing dimension) of the numerical ratio (i.e.
161 approximately 1:5), and hence the underlying dimensions (item size and total surface area for Size,
162 convex hull and density for Spacing) were also at a constant ratio with number. In a Number-Size
163 congruent item, both item size and total surface area were congruent with number, while they were
164 both incongruent with number in a Number-Size incongruent item. The same was true for convex
165 hull and density when Spacing was the congruency-related dimension. As mentioned above, the third
166 dimension (not congruency-related) was constant between the two sets of dots, and across the
167 items. For instance, Size was constant across the two sets of dots and took the same value in the
168 Spacing-congruent and the Spacing-incongruent trials. The underlying dimensions (e.g. item size and
169 total surface area for *Size*) were also at a constant ratio between the two sets of dots and across the
170 items. The 16 combinations of number pairs were each presented ten times across the whole task.
171 The 4 possible combinations of the side of the correct response were also counterbalanced across
172 the total number of trials in the task.

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173 **Figure 1: Examples of between-dimension trials.** Both in the prime and the probe items of the trial,
174 the congruency-related dimension can be congruent or incongruent with Number. In a between-
175 dimension trial, the congruency-related dimensions in the prime and the probe items are different.

176

177 The task started with the presentation of 4 training trials (one for each of the 4 possible congruency
178 pairs, 2 within- and 2 between-dimension pairs, 2 with Size as the congruency-related dimension),
179 during which feedback on accuracy was provided. The task was divided in 5 blocks of 32 trials, for a
180 total duration of approximately 15 to 20 minutes.

181 3. Results

182 For each participant, we removed trials with reaction times faster than 150ms and slower than 3
183 standard deviations above the individual mean. This led to removing 2.54% of the full dataset. One
184 participant was removed due to their average reaction time being slower than 3 standard deviations
185 above the average reaction time of the sample. In order to ensure that participants were sufficiently
186 attentive and engaged with the experiment to yield reliable/valid behavioral data, we restricted our
187 analyses to participants who performed above 75% of accuracy rate in each of the four conditions
188 (congruent or incongruent with Size or Spacing) to be able to analyze potential congruency sequence

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189 effect. Sixteen participants were removed based on this criterion. The analyses described below were
190 thus run on a sample of 64 participants, meeting the requirements of our power analysis¹.

191 3.1. Analyses of the prime items

192 A 2 (Dimension: Size, Spacing) x 2 (Congruency: congruent, incongruent) repeated measures ANOVA
193 on the reactions times for the correctly responded prime items showed a main effect of Congruency,
194 $F(1, 63) = 117.12, p < .0001, \eta^2_p = .65$, and a significant Congruency x Dimension interaction, $F(1, 63) =$
195 $16.86, p < .0001, \eta^2_p = .21$. Post-hoc one-way ANOVAs revealed that the congruency effects for each
196 non-numerical dimension were both significant, with a stronger number/Spacing congruency effect
197 (incongruent : $M = 623, 95\% CI [595.5, 650.5]$, congruent: $M = 533, 95\% CI [514.6, 551.4]$), $F(1,63) =$
198 $113, p < .0001, \eta^2_p = .64$), than number/Size congruency effect (incongruent: $M = 598, 95\% CI [574.4,$
199 $621.6]$, congruent: $M = 559, 95\% CI [533.3, 584.7]$), $F(1, 63) = 19, p < .0001, \eta^2_p = .23$.

200 3.2. Analyses of the congruency sequence effects

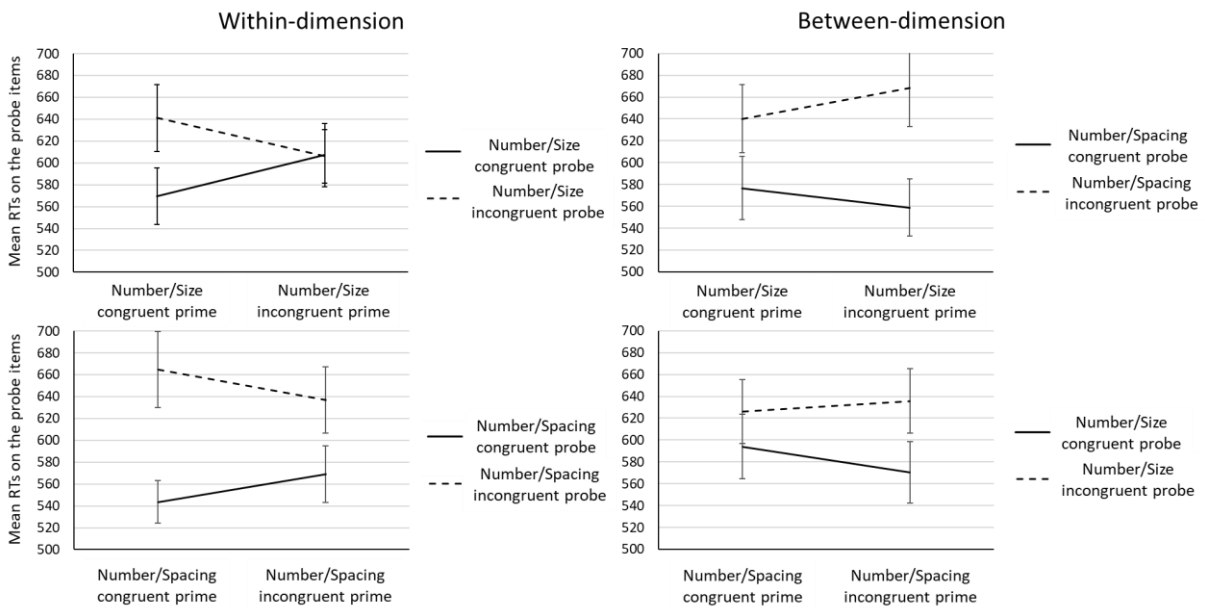
201 The analyses of the congruency sequence effects were run on the reaction times for the correct
202 responses on the probe items following correct responses on the prime items. We first ran a 2 (Prime
203 dimension: Size or Spacing) x 2 (Probe dimension: Size or Spacing) x 2(Prime congruency: congruent
204 or incongruent) x 2 (Probe congruency: congruent or incongruent) repeated measures ANOVA on the
205 reaction times. As for the analyses of the prime items, we found a significant main effect of the
206 probe's Congruency, $F(1, 63) = 142.53, p < .0001, \eta^2_p = .69$, as well as a significant interaction
207 between the probe's Congruency and Dimension, $F(1, 63) = 17.89, p < .001, \eta^2_p = .22$, indicating again
208 a stronger congruency effect for Spacing (incongruent: $M = 653, 95\% CI [636.7, 669.3]$, congruent: M
209 $= 562, 95\% CI [549.5, 574.5]$), than for the Size dimension (incongruent: $M = 627, 95\% CI [612.9,$

¹ We ran an a priori power analysis using G*Power, Version 3.1; Faul et al., 2009) in order to estimate the sample size. Based on the effect size of the negative priming effect in the non-symbolic comparison task found in adults ($\eta_p^2 = .29$, Viarouge et al., 2019), we chose a conservative effect size of $\eta_p^2 = .2$. The analysis indicated that a sample size of 55 was necessary to detect such effect size in a 2 (irrelevant dimension in the prime) x 2 (irrelevant dimension in the probe) x 2 (prime congruency) x 2 (prime congruency) repeated measures ANOVA with a power of .95 ($\alpha = .05$).

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210 641.1], congruent: $M = 585$, 95% CI [571.1, 598.9]). Importantly, we observed a significant 4-way
 211 interaction, $F(1, 63) = 48.73$, $p < .001$, $\eta^2_p = .44$. Separate post-hoc 2(Probe dimension) x 2 (Probe
 212 congruency) x 2 (Prime congruency) ANOVAs with Bonferroni corrected p-values for each of the
 213 prime dimensions showed significant three-way interactions (Size: $F(1, 63) = 27.3$, $p < .001$, $\eta^2_p = .3$
 214 and Spacing: $F(1, 63) = 19.1$, $p < .001$, $\eta^2_p = .23$), which we explored further by running separate 2
 215 (Prime congruency) x 2 (Probe congruency) ANOVAs with Bonferroni corrected p-values for each of
 216 the four combinations of the prime and probe non-numerical dimensions. Each of the four analyses
 217 revealed significant interactions between the congruency of the prime and the probe items (Size x
 218 Size : $F(1, 63) = 30$, $p < .0001$, $\eta^2_p = .32$, Size x Spacing : $F(1, 63) = 10.1$, $p = .002$, $\eta^2_p = .14$, Spacing x
 219 Size : $F(1, 63) = 5.74$, $p = .02$, $\eta^2_p = .08$, Spacing x Spacing : $F(1, 63) = 15.1$, $p < .001$, $\eta^2_p = .19$; see
 220 Figure 2).

221



222

223 **Figure 2: Congruency Sequence Effects.** reaction times (ms) in the congruent and incongruent probe
 224 items depending on the congruency of the prime items, for the within-dimension (on the left) and
 225 between-dimension (on the right) trials. Error bars represent 95% confidence intervals.

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227 These significant interactions reflected different patterns of results (see Table 1). When the
 228 irrelevant non-numerical dimension of the prime and the probe items were the same (within-
 229 dimension trials), the congruency effects on the probe items were smaller for incongruent than for
 230 congruent prime items, reflecting a typical Gratton effect. However, this was not the case when the
 231 irrelevant non-numerical dimension of the prime and the probe items were different (between-
 232 dimension trials). In this condition, we observed a reversed Gratton effect, with a larger congruency
 233 effect on the probe items after an incongruent than after a congruent prime item.

		Within-dimension			
		Size-Size		Spacing-Spacing	
		Congruent Prime	Incongruent Prime	Congruent Prime	Incongruent Prime
Congruent Probe		<i>M</i> = 570, 95% CI [544.3, 595.7]	<i>M</i> = 607, 95% CI [578, 636]	<i>M</i> = 544, 95% CI [524.6, 563.4]	<i>M</i> = 569, 95% CI [543.2, 594.8]
Incongruent Probe		<i>M</i> = 641, 95% CI [610.3, 671.7]	<i>M</i> = 606, 95% CI [581.6, 630.4]	<i>M</i> = 665, 95% CI [630, 700]	<i>M</i> = 637, 95% CI [606.5, 667.5]

		Across-dimension			
		Size-Spacing		Spacing-Size	
		Congruent Prime	Incongruent Prime	Congruent Prime	Incongruent Prime
Congruent Probe		<i>M</i> = 577, 95% CI [548.1, 605.9]	<i>M</i> = 559, 95% CI [532.9, 585.1]	<i>M</i> = 594, 95% CI [564.7, 623.3]	<i>M</i> = 570, 95% CI [541.9, 598.1]
Incongruent Probe		<i>M</i> = 640, 95% CI [608.7, 671.3]	<i>M</i> = 669, 95% CI [633.5, 705.5]	<i>M</i> = 626, 95% CI [596.7, 655.3]	<i>M</i> = 636, 95% CI [606.5, 665.5]

234
 235 **Table 1.** Mean reaction times (ms) and 95% confidence intervals for each of the 16 trial conditions.

236 4. Discussion

237 This study aimed at testing the specificity of the inhibitory control processes at play in the non-
 238 symbolic numerical comparison task, using a conflict adaptation paradigm. First, we observed classic
 239 congruency effects between number and non-numerical dimensions of magnitude in the prime
 240 items. Interestingly, we found stronger congruency effects between number and Spacing than
 241 between number and Size, in line with studies indicating a stronger influence of extrinsic dimensions

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242 (such as convex hull or occupied space) than intrinsic dimensions (such as individual item size) in
243 adults (Gilmore et al., 2016). Since the ratios between number and the non-numerical dimensions
244 were identical for Size and Spacing, this result could indicate a higher salience of the Spacing
245 dimension than the Size dimension.

246 Second, our analyses of the congruency sequence effects showed significantly different patterns
247 between the within- and between-dimension pairs. When the irrelevant non-numerical dimension
248 was identical between the prime and the probe items, the congruency effect was reduced after
249 incongruent primes, showing a classic congruency sequence effect (i.e., Gratton effect). On the
250 contrary when the irrelevant non-numerical dimensions in the primes and in the probes were
251 different, we observed a reversed Gratton effect with larger congruency effects following the
252 incongruent primes. Taken together, these results indicate that the inhibitory control processes
253 involved in the non-symbolic comparison task are specific to the non-numerical dimension conflicting
254 with number.

255 Previous studies have argued that conflict adaptation was mainly due to an improved processing of
256 the relevant information (Notebaert & Verguts, 2008). In our task, the relevant information remains
257 constant throughout the task, thus an improved processing of the relevant information cannot in and
258 by itself explain the different patterns observed between the within- and between-dimension trials,
259 supporting the role of inhibitory control processes in the observed congruency sequence effect. It is
260 important to note that other accounts based on binding effects have been proposed for the Gratton
261 effect, which do not involve conflict adaptation (Schmidt & De Houwer, 2011). While conflict
262 adaptation is unlikely to be the sole underlying mechanism of the Gratton effect, several studies have
263 shown that the latter remained even after controlling for possible binding confounds (Akçay &
264 Hazeltine, 2007; Blais et al., 2014).

265 Although observed in previous studies (Notebaert & Verguts, 2008; Brown, Reynolds & Braver, 2007),
266 the increased congruency effects following incongruent prime items observed in the between-

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267 dimension conditions is can be surprising. One possible interpretation, further supporting the
268 dimension-specific nature of the inhibitory control involved in our task, is in terms of switch cost
269 between the prime and the probe items when the irrelevant non-numerical dimensions changes. This
270 account predicts in particular that, in between-dimension trials, the performances are impaired in an
271 incongruent probe immediately following an incongruent prime, due to the cost of switching from
272 the specific inhibition of the previously conflicting information of magnitude to the currently
273 conflicting new information of magnitude. While Notebaert and Verguts (2008) proposed a similar
274 account in terms of switch cost at the level of responses (see also Brown, Reynolds & Braver, 2007,
275 for a similar account at the task level), here our results suggest that this switch cost can not only
276 impact the activation of the relevant information in the task, but also the processing of the irrelevant
277 information. Following this account, the presence of a reverse Gratton effect further supports a
278 dimension-specific inhibitory control in our task.

279 We would like to stress the fact that our study evidenced a specificity of inhibitory control solely in
280 regards to the manipulated Size and Spacing dimensions, which are each defined as a combination of
281 two covarying dimensions of magnitudes (average item size and total surface for Size, convex hull
282 and density for Spacing), commonly used in the literature (Gebuis & Reynvoet, 2011). Our design
283 does not allow to disentangle the role of these four dimensions in our study, and whether one or a
284 combination of the two dimensions composing our manipulated dimensions drove the observed
285 effects. Further studies would be very interesting to explore the specificity of inhibitory control
286 relative to each of these dimensions.

287 Our study is the first to demonstrate that the mechanisms involved in the attention to number are
288 specific to the irrelevant information conflicting with number, and contributes to better
289 characterizing the executive mechanisms at play in numerical cognition. Using brain imaging
290 methods, further research could allow to further identify the precise neural networks underlying this
291 specificity. More generally, by using a task whereby the relevant information is maintained constant,

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292 our study demonstrates that the inhibition of the irrelevant information plays an important role in
293 the Gratton effect, which appears to not be solely driven by the increased activation of the relevant
294 information.

295

296 **Acknowledgments**

297 **Declarations of interest:** none.

298

299 **Appendix A.**

300 Below is a table showing the congruency and the ratios for each of the four magnitudes composing
301 the Size and Spacing dimensions manipulated in our study (Table A1), as well as examples of the
302 stimuli for a within-dimension and a between-dimension conditions (Figure A1 and A2).

303 The ratios in the table are always calculated from our stimuli, as the smaller value over the larger
304 value of a given dimension (e.g. for item size, ratio = (item size in the set with smaller dots) / (item
305 size in the set with larger dots)). Thus, when the item is congruent ("C" in the table), this ratio
306 corresponds to the value of the dimension in the less numerous set over the value in the more
307 numerous set, and vice versa for incongruent items ("I" in the table). In some cases, there is a small
308 jitter between the items within a condition. It was easier to generate sets of dots with precise values
309 for Size and its sub-dimensions than for Spacing. For instance, ratio of item size in number-Size
310 congruent items and ratio of total surface area in number-Size incongruent items are exactly the
311 same in all the items. Since our numerical ratio was approximately the same across all the trials
312 (~3:5), but using different number pairs, the ratios differ slightly between the four pairs. The same
313 applies for Spacing and its sub-dimensions (convex hull and sparsity), with a bit less precision due to
314 our program generating sets of dots until the convex hull surface falls within a small range of values.

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	<i>Size</i>		<i>Spacing</i>	
	item size	total surface area	convex hull	sparsity
Number- <i>Size</i> congruent	C ratio = .58	C mean ratio = .35, sd = .01	C mean ratio = .76, sd = .03	I mean ratio = .78, sd = .03
Number- <i>Size</i> incongruent	I mean ratio = .35, sd = .01	I ratio = .58	C mean ratio = .77, sd = .02	I mean ratio = .78, sd = .02
Number- <i>Spacing</i> congruent	I mean ratio = .77, sd = .01	C mean ratio = .77, sd = .01	C mean ratio = .34, sd = .01	C mean ratio = .57, sd = .01
Number- <i>Spacing</i> incongruent	I mean ratio = .77, sd = .01	C mean ratio = .77, sd = .01	I mean ratio = .58, sd = .01	I mean ratio = .35, sd = .01

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326 **Table A1.** Congruency (C: congruent, I: incongruent) and ratios for each magnitude composing the
 327 Size and Spacing dimensions, in each of the four experimental conditions. Ratios are calculated as the
 328 smaller value over the larger value for a given dimension. Values for the magnitudes composing the
 329 congruency-related dimension are in bold.

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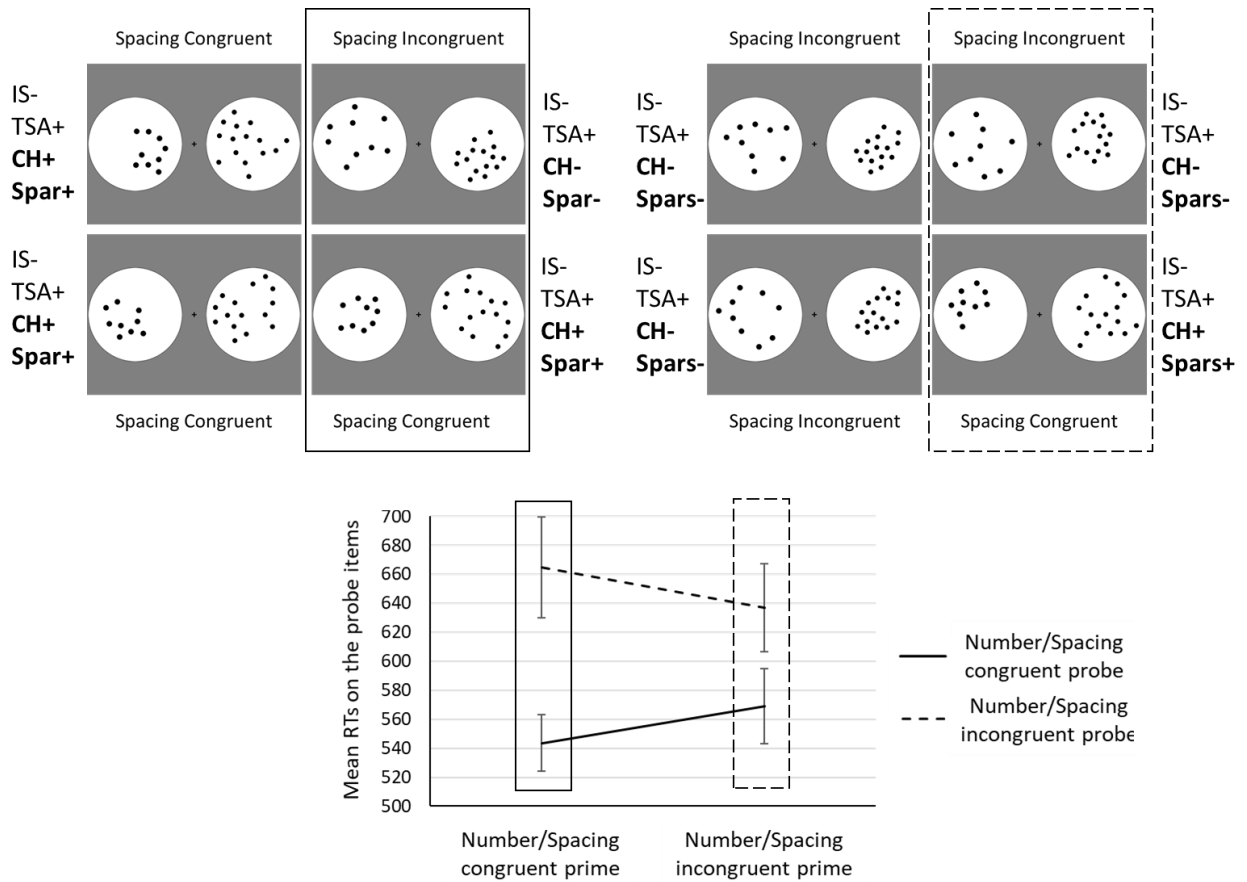
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348 **Figure A1.** Example of stimuli in the within-dimension conditions, with Spacing as the congruency-
 349 related dimension. Next to each stimulus is the congruency of item size (IS), total surface area (TSA),
 350 convex hull (CH) and sparsity (Spars). + : congruent with number ; - : incongruent with number.
 351 Dimensions composing the manipulated dimension are in bold.

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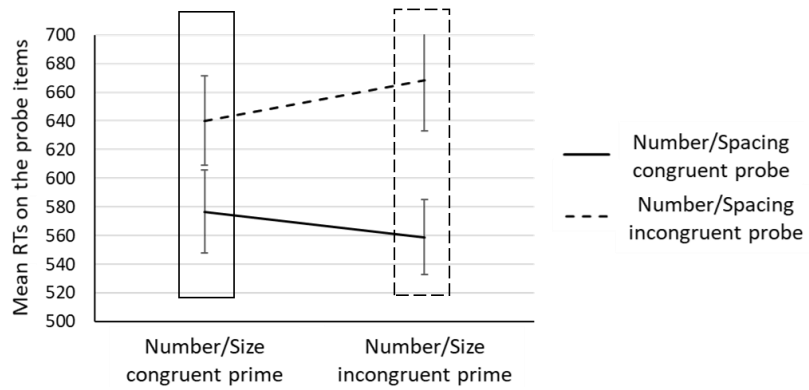
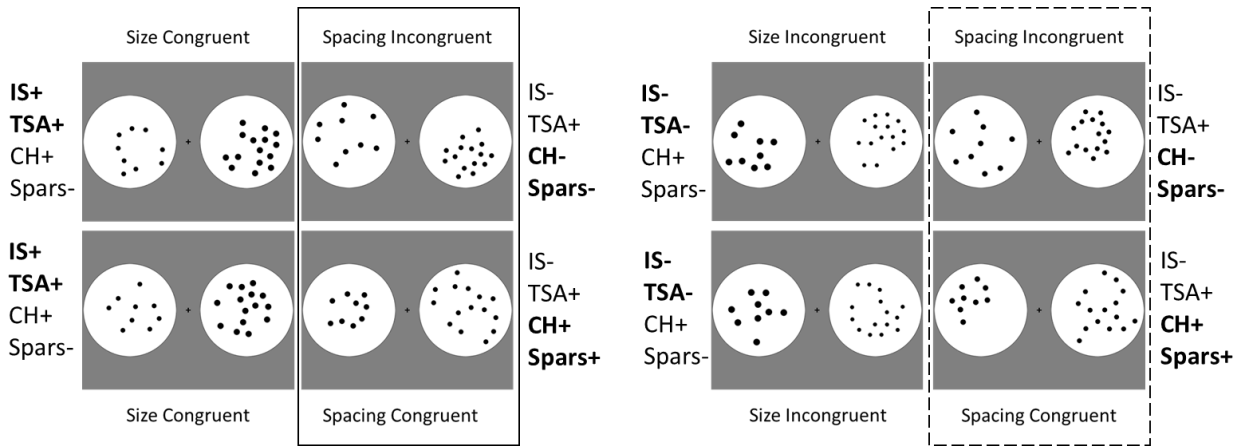
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365 **Figure A2.** Example of stimuli in the between-dimension conditions, with Size as the congruency-
 366 related dimension in the prime items. Next to each stimulus is the congruency of item size (IS), total
 367 surface area (TSA), convex hull (CH) and sparsity (Spars). + : congruent with number ; - : incongruent
 368 with number. Dimensions composing the manipulated dimension are in bold.

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