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Proportion Congruent effects in the absence of Sequential Congruent effects

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A debated question in the cognitive control field is whether cognitive control is best conceptualized as a collection of distinct control mechanisms or a single general purpose mechanism. In an attempt to answer this question, previous studies have dissociated two well-known effects related to cognitive control: sequential congruence and proportion congruent effects. In the present experiment, we pursued a similar goal by using a different strategy: to test whether proportion congruent effects can be present in conditions where sequential congruence effects are absent. We used a paradigm in which two conflict types are randomly intermixed (Simon and Spatial Stroop) and the proportion of congruency is manipulated for one conflict type and kept neutral for the other conflict type. Our results showed that in conflict type alternation trials, where sequential congruence effects were absent, proportion congruent effects were still present. It can be concluded that, at least under certain circumstances, sequential congruence and proportion congruent effects can be independent of each other and specific to the conflict type.

Cognitive control can be defined as a set of processes that allows behavior to adapt flexibly in response to our goals. To study cognitive control in the lab, interference tasks are often used. These tasks introduce conflict between goals and actions afforded by the stimuli, and allow researchers to study how these conflicts are solved. For example, in the

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classical Stroop color-naming task (for a review see Macleod, 1991) participants are required to name the color in which color words are displayed. Response times (RTs) are reliably slower for trials in which the name of the printed word is incongruent with its color (e.g., the word RED printed in green) compared to trials in which the word and color are congruent (e.g., the word RED printed in red). This difference in performance (which is known as a congruency effect) provides a measure of the contribution of irrelevant word reading to performance, with greater amounts of word reading leading to larger differences in performance between congruent and incongruent trials (i.e., larger interference). In more general terms, incongruent trials constitute a conflict for the system, and congruency effects reflect the time that the system needs to implement control and resolve the conflict.

Two particular contexts that produce dynamic variation in congruency effects have been used often to study cognitive control. On the one hand, sequential congruent (SC) effects are defined by a reduction in the congruency effect on a current trial when preceded by an incongruent trial compared to when preceded by a congruent trial (Botvinick, Nystrom, Fissell, Carter, & Cohen, 1999; Gratton, Coles, & Donchin, 1992; Kerns et al., 2004; Kunde & Wühr, 2006; Riggio, Gherri, & Lupiáñez, 2012). On the other hand, proportion congruent (PC) effects are measured by manipulating the relative proportions of congruent and incongruent trials within an experimental block. The magnitude of the congruency effect varies with the proportion of congruent trials, being larger in the context of a high proportion of congruent trials than in the context of a low proportion of congruent trials (e.g. Carter et al., 2000; Logan & Zbrodoff, 1979; Lowe & Mitterer, 1982; West & Baylis, 1998).

Some prominent theories have argued that SC and PC effects are the very same process (Blais, Robidoux, Risko, & Besner, 2007; Botvinick, Braver, Barch, Carter, & Cohen, 2001; Verguts & Notebaert, 2008). Specifically, they argue that both SC and PC effects are the result of a single reactive cognitive control system, which first detects and evaluates on-going information for potential response conflict and then resolves that conflict by reinforcing top-down biasing processes associated with the current task set. Thus, it is not surprising to observe a reduction in congruency effects in blocks with a low proportion of congruent trials, as these blocks also have a high proportion of iI transitions (i.e., incongruent trials preceded by incongruent trials). This way, the mechanism that produces the SC effect could also produce the PC effect.

In other words, it is logic that sequential congruent effects produce proportion congruent effects since having a context with high proportion of incongruent trials necessary leads to frequent incongruent-incongruent transitions. However, this does not necessarily lead to the conclusion that PC effects are actually SC effects in disguise. In fact, recent studies in our lab have questioned that argument by showing behavioural dissociations between SC and PC effects within the context of conflict tasks (Funes, Lupiáñez, & Humphreys, 2010b; Torres-Quesada, Funes, & Lupiáñez, 2013). For example, Funes et al. (2010b) reported an experiment in which sequential effects were specific to conflict type (they disappeared when conflict type changed between Stroop and Simon across consecutive trials), but PC effects were not specific to conflict type (i.e., PC effects transferred from one conflict type to the other).

The finding that SC effects were conflict type specific in this study has proved to be a quite stable defining property of SC effects, as it has been found consistently across many studies and labs using a variety of different conflict types (for a review see Egner, Delano, & Hirsch, 2007; Notebaert & Verguts, 2008; Wendt, Kluwe, & Peters, 2006). In contrast, the conflict type generality of PC effects appears to be less consistent. In fact, under some conditions PC effects have been shown to be item and/or context specific within the same conflict type (Crump, Gong, & Milliken, 2006; 2008; Jacoby, Lindsay, & Hessels, 2003). In these studies, proportion congruent is manipulated independently for two sets of stimuli (Jacoby, et al., 2003) or for two contexts (Cañadas, Rodríguez-Bailón, Milliken, & Lupiáñez, in press; Crump, et al., 2006), such that one set of items or one context is associated with a high (or low) proportion of congruent trials, whereas another set of items or context is associated with a low (or high) proportion of congruent trials. The key result is again larger congruency effects for the items or contexts associated with a high proportion of congruent trials.

In any case, dissociating the two effects on the basis of the way they act under certain conditions (i.e., being either conflict-type specific or general) does not rule out the fact that, in nature, sequential congruent effects might be embedded in proportion congruent effects, with the very same mechanism underlying both. Therefore, in the current paper we looked for a stronger source of evidence which could clearly show that proportion congruent effects ought to be explained by a mechanism different from the mechanism underlying SC effects. Based on the robust finding that SC effects are completely absent on conflict type alternations (Egner, et al., 2007; Funes, Lupiáñez, & Humphreys, 2010a; Wendt, et al., 2006), we investigated whether PC effects are present on conflict type alternation trials, where no SC effects occur. If such a result were to be found, it would constitute a strong piece of evidence that PC effects can be caused by a different mechanism than SC effects.

METHOD

Participants. Forty-eight undergraduate psychology students (36 females; 5 left handed) from the University of Granada and McMaster University participated in the experiment. Their ages ranged from 17 to 31 (with a mean age of 20). All had normal or corrected to normal vision, were naive to the purpose of the experiment, and received course credit for participation. The experiment was conducted in accordance with the ethical guidelines laid down by the Department of Experimental Psychology, University of Granada, and the McMaster University Research Ethics Board.

Apparatus and Stimuli. Participants were tested on a Pentium computer running E-prime software (Schneider, Eschman, & Zuccolotto, 2002a, 2002b), and responded to stimuli presented on a 15-inch color Samsung monitor at a viewing distance of about 57 cm. All the stimuli consisted of white arrows pointing either up or down, and subtending 0.54° of visual angle in width and 1.08° in length. The target could appear in one of four possible locations; left, right, above or below fixation (a plus sign in the centre of the screen). The four target locations were equidistant to fixation (4.32°). Responses were made by pressing either the "v" key (left response) on the keyboard with the index finger of the left hand or the "m" key (right response) with the index finger of the right hand.

Procedure. Participants were instructed to make left/right key presses in response to the up/down direction of an arrow. Half the participants responded to the "up" direction by pressing the letter "v" (left response) with the index finger of their left hand and to the "down" direction by pressing the letter "m" (right response) with the index finger of their right hand. The opposite mapping was used for the other participants. For targets appearing on the vertical axis, that is, above or below fixation, a pure Spatial Stroop effect (i.e., stimulus-stimulus interference) was measured. In contrast, for targets appearing on the horizontal axis, that is, left or right of fixation, a pure Simon effect (i.e., stimulus-response interference) was measured. Within each block, half of the trials were Simon conflict trials and the other half were Spatial Stroop conflict trials. Trials were congruent whenever the arrow location corresponded with the arrow direction (in the case of Spatial Stroop trials) or with the response location (in the case of Simon trials). On the other hand, incongruent trials were defined as those where the arrow location did not correspond with the arrow direction or the response location (for Spatial Stroop and Simon, respectively). The instructions stressed the need to respond as fast as possible while trying to avoid error. Participants were asked to maintain fixation at the centre of the screen before the target was presented.

The sequence of events on each trial was as follows. The fixation point was displayed for 750 ms, after which the target was displayed for 100 ms. Following offset of the target, the fixation point remained alone on the screen until participants' response or for 1500 ms if there was no response. Auditory feedback (a 500 Hz, 50 ms computer-generated tone) was given on error trials, or on trials in which no response was made within 1500 ms. The inter-trial-interval (ITI) was 1000 ms long. Trials were grouped in blocks and presented randomly within each block. The experiment stopped between blocks. Participants were instructed to rest for a few seconds between blocks, and then resume the experiment by pressing the space bar.

The experiment consisted of 16 practice trials (not included in the statistical analysis), followed by 512 experimental trials. There were three within-participants factors: proportion congruent, conflict type, and congruency. Proportion congruent was manipulated within each block and applied only to the Simon trials. In the high proportion congruent condition, 75% of the Simon trials were congruent and 25% were incongruent, while in the low proportion congruent condition, 25% of the Simon trials were congruent and 75% were incongruent. Stroop trials were 50% congruent (and 50% incongruent) in all conditions. Importantly, Simon and Spatial Stroop trials were intermixed randomly within each block of trials, with equal proportions of the two conflict types in each block.

The experimental trials within a block were divided into sequences within which the proportion congruent remained constant, but then proportion congruent varied between these sequences within-subject. We refer to the length of these sequences using the label transition length, and this transition length varied between three groups of participants. For one group, proportion congruent alternated every 32 trials (i.e., every block) from high proportion congruent to low proportion congruent or vice versa. For another group, the proportion congruent alternated every 64 trials (i.e., every two blocks). And for a final group, the proportion congruent alternated every 128 trials (i.e., every four blocks). Ultimately, this variable did not affect performance in any way, and so, although it was included in analyses, it will not be discussed further.

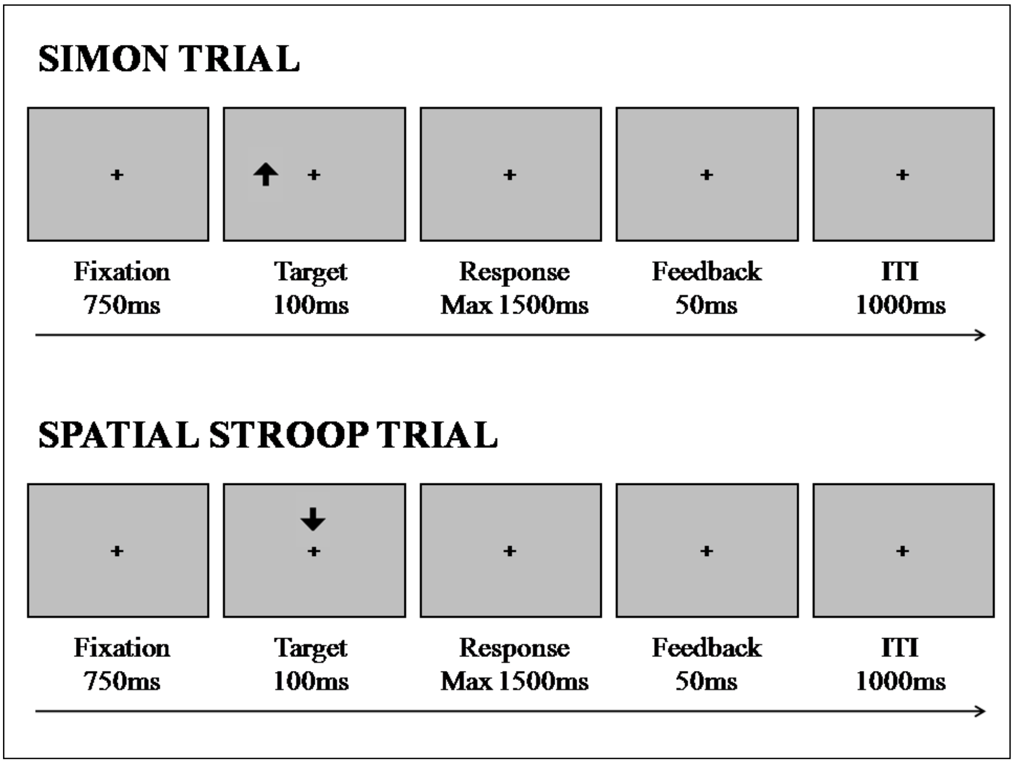

Figure 1. Sequence of events for Simon (top panel) and Stroop (bottom panel) trials. The two types of trials were randomly mixed within each block of trials. On Simon trials targets are presented to the left/right of the fixation cross, whereas on Spatial Stroop trials targets are presented above/below the fixation cross.

Design. In addition to these variables, we recoded sequential effects offline by creating two additional within-subject variables (previous congruency and conflict type shift). The previous congruency variable was created to code the level of congruency encountered on the previous trial, and took two possible levels, congruent and incongruent. The conflict type shift coded whether the type of conflict encountered on the current trial constituted a repetition or an alternation of the kind of conflict encountered on the previous trial. Conflict type repetition trials consisted of a Spatial Stroop trial followed by another Spatial Stroop trial (both appearing along the vertical axis), or a Simon trial followed by another Simon trial (both appearing along the horizontal axis). Conflict type alternation trials consisted of any Spatial Stroop trial in the vertical axis preceded by a Simon trial in the horizontal axis or vice versa.

RESULTS

Mean RTs for each condition were calculated after excluding RTs more than 2.5 standard deviations from the overall mean, and RTs on trials in which an error was made. This procedure eliminated 2.3% and 6.6% of the trials, respectively. Furthermore, trials following an error and the first trial of each block were also excluded, which eliminated a further 10% of the trials from the analysis of RTs. For the analysis on error rates, only the first trial of each block and trials following an error were excluded.

Besides, one participant was discarded due to high errors rate (above 2.5 standard deviations from the overall mean).

Separate ANOVAs were carried out to analyse PC effects and SC effects to test our predictions.

SC effects

To analyse the previous congruency by congruency second-interaction further, mean RTs and error rates were submitted to separate ANOVAs that included conflict type shift, previous congruency and congruency as within participant factors, and transition length as a between participants factor. In the analysis of RTs, there was a significant main effect of congruency, $F(1,44)=167.40$, $p<.001$, which interacted with previous congruency, $F(1,44)=87.74$, $p<.001$, revealing the typical sequential congruence pattern. More important, this interaction was modulated by conflict type shift, $F(1,44)=162.2$, $p<.001$. To analyse this interaction further, separate analyses were conducted for the two conflict type shift conditions. For conflict type repeated trials, the SC effect (i.e., the congruency by previous congruency interaction) was significant, $F(1,44)=191.8$, $p<.001$, with a 67 ms congruency effect for previous congruent trials and a -8 ms congruency effect for previous incongruent trials. In contrast, for conflict type alternation trials, the SC effect was not significant ($F<1$), with a congruency effect of approximately 33 ms for both previous congruent and previous incongruent trials (see Figure 2).

In the analysis of error rates, there was also a significant main effect of congruency, $F(1,44)=48.64$, $p<.001$, with a higher error rate for incongruent trials (.09) than for congruent trials (.05). This effect was modulated by previous congruency, $F(1,44)=58.25$, $p<.001$, and, as in the RT analysis, this SC effect was also modulated by conflict type shift, $F(1,44)= 37.05$, $p<.001$. The SC effect was significant for conflict type repeated trials, $F(1,44)=59.36$, $p<.001$ with .10 and -.01 congruency effects for previous congruent and incongruent trials, respectively. In contrast, the SC effect was not significant for conflict type alternation trials ($F<1$, with a .05 congruency effect for both previous trial types).

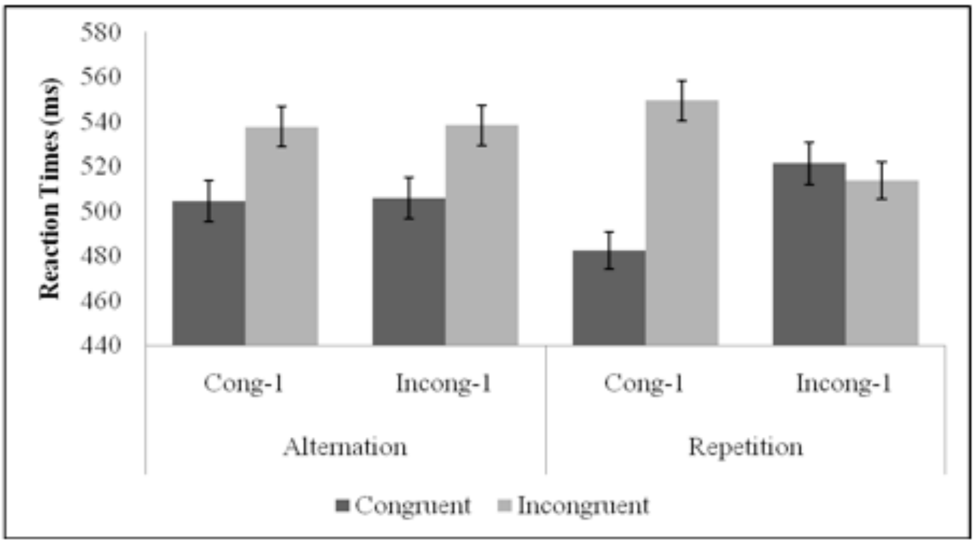

Figure 2. Mean reaction times for congruent and incongruent trials as a function of previous congruency [previous congruent (cong-1) vs. previous incongruent (incong-1)] and shift of conflict type (alternation or repetition of conflict type across consecutive trials). Note that sequential congruent effects are only observed for conflict type repetition trials.

PC effects in the absence of SC effects

Next, we examined whether the proportion congruent effect occurred in the absence of SC effects. The ANOVAs included proportion congruent, conflict type and congruency as within participant factors and transition length as a between participants factor. Importantly, we performed these analyses exclusively on conflict-type alternation trials, as the above analyses showed clearly that sequential congruent effects are completely absent on these trials (see Figure 3).

In the analysis of RTs, the key finding was a significant interaction between congruency, proportion congruent, and conflict type, $F(1,44)=16.38$, $p<.001$. Separate analyses for the two conflict types revealed a significant interaction between proportion congruent and congruency for the Simon conflict type, $F(1,44)=17.86$, $p<.001$, with congruency effects of 48 ms and 23 ms for the high and low proportion congruent conditions, respectively. In contrast, the proportion congruent by congruency interaction was not significant for the Spatial Stroop conflict type, $F(1,44)=1.54$, $p=.225$, with congruency effects of 28 ms and 35 ms for the high and low proportion congruent conditions, respectively.

The analysis of error rates revealed a similar pattern. There was a significant interaction between congruency, proportion congruent, and conflict type, $F(1,44)=4.42$, $p=.04$. Separate analyses for the two conflict types revealed a significant congruency by proportion congruent interaction for the Simon conflict type [$F(1,44)=17.28$, $p<.001$, with congruency effects of .11 and .05 for the high and low proportion congruent conditions, respectively], and a non-significant interaction for the Spatial Stroop conflict type [F(1,449=2.83, p=.099, with congruency effects of .04 and .02 for high and low proportion congruent conditions, respectively].[1]

PC effects in the presence of SC effects

In order to confirm that PC effects were also onserved when SC were present, we carried out the same ANOVA that in the previous analysis but only for conflict type repetitions trials.

In the analysis of RTs, we observed a significant interaction between congruency, proportion congruent, and conflict type, $F(1,44)=55.93$, $p<.001$. Separate analyses for the two conflict types revealed a significant interaction between proportion congruent and congruency for the Simon conflict type, $F(1,44)=89.55$, $p<.001$, with congruency effects of 68 ms and -5 ms for the high and low proportion congruent conditions, respectively. In

[1] To rule out the possibility that the influence of n-2 trial congruency on current congruency trial (n-2 SC effects) would explain the presence of PC effects (therefore, we could not claim that SC effects were absent), we tested whether PC effects were present when both n-2 and n-1 sequential congruent effects were absent (thus, conflict type alternations from n-2 to n and from n-1 to n). We observed a proportion of congruency, conflict type and congruency significant interaction ($F(1,44)=4.38$, $p=.042$), showing significant PC effects for Simon conflict ($F(1,44) = 9.61$, $p= .003$) but no for Spatial Stroop ($F<1$).

contrast, the proportion congruent by congruency interaction was not significant for the Spatial Stroop conflict type, $F(1,44)=2.44$, $p=.126$, with congruency effects of 30 ms and 23 ms for the high and low proportion congruent conditions, respectively.

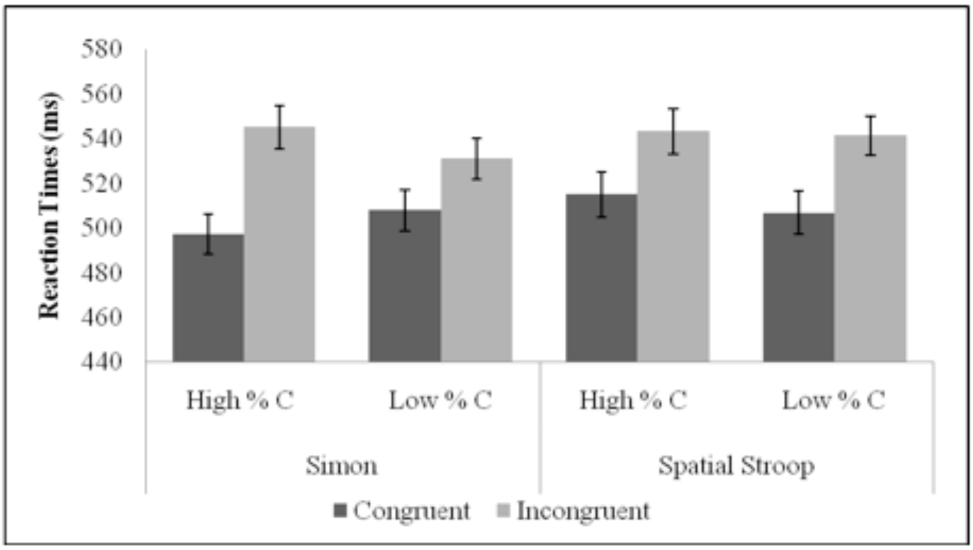

Figure 3. Mean reaction times for congruent and incongruent trials as a function of proportion congruency [high proportion of congruent trials (high % C) vs. low proportion of congruent trials (low % C)] and conflict type (Simon and Spatial Stroop), and only including in the analysis conflict type alternation trials (where sequential congruent effects are not present). Note that the observed PC effect was specific to the conflict type on which proportion of congruency was manipulated (i.e, Simon trials).

The analysis of error rates revealed a similar pattern. There was a significant interaction between congruency, proportion congruent, and conflict type, $F(1,44)=18.10$, $p<.001$. Separate analyses for the two conflict types revealed a significant congruency by proportion congruent interaction for the Simon conflict type [$F(1,44)=27.83$, $p<.001$, with congruency effects of .14 and almost .0 for the high and low proportion congruent conditions, respectively], and a non-significant interaction for the Spatial

Stroop conflict type [$F<1$, with congruency effects of .04 and .03 for high and low proportion congruent conditions, respectively].

DISCUSSION

The key research question addressed here was whether PC effects can be caused by a different mechanism than SC effects. Our research strategy was to examine PC effects on conflict type alternations, as many prior studies have shown that SC effects disappear when conflict type alternates across consecutive trials (for a review see Egner, et al., 2007; Funes, et al., 2010a; Wendt, et al., 2006). Importantly, PC effects were indeed observed on conflict alternation trials, where no SC effects occurred. In other words, congruency effects measured on the horizontal axis (Simon) trials did not depend at all on whether the previous vertical axis (Stroop) trial was congruent or incongruent. At the same time, congruency effects measured on the horizontal axis (Simon) trials did depend on whether there were a lot or just a few congruent Simon trials in that particular block, even if in the previous trials the target appeared on the vertical axis, thus producing Stroop conflict. The implication is that the local context offered by the immediately preceding vertical axis trial had no influence on congruency effects, while the broader block-wide context offered by other horizontal axis trials did have an impact on performance.

We also observed that this PC effect was specific to conflict type, that is, it occurred only for the Simon conflict type trials for which proportion of congruency was manipulated. Therefore, in contrast to the pattern observed in two other recent studies (Funes, et al., 2010b; Torres-Quesada, et al., 2013), both PC and SC effects in the present study were specific to conflict type. Nonetheless, the conclusion we draw here is similar to that drawn in those prior studies; the two effects might be caused at least in part by separate processes. Here, this conclusion follows from the finding that one effect can be observed in the absence of the other.

However, the fact that PC effects are different from SC effects, does not mean that they are independent since the manipulation of the proportion congruent necessarily leads to different sequential congruent situations. Nevertheless, our data clearly show that there are some PC effects that cannot be explained by the very same mechanism than SC effects, since they occurred in the absent of SC effects. For that reason, we believe the present procedure and strategy for analysis can be used as a tool to measure pure PC effects. That is, in this paper we provide a procedure to separate PC effects that can be explained by SC effects from PC effects that cannot be explained on the basis of the accumulation of SC effects. Besides, we have further confirmed the presence of PC effects in the absence of SC effects in a follow-up experiment (Torres-Quesada, Lupiáñez, Milliken, & Funes, submitted), where we also showed that those "pure" PC effects were found when Simon was the conflict where the proportion of congruency took place as well as when Spatial Stroop was the manipulated conflict.

Regarding what kind of mechanisms underlie both effects, SC effects are commonly interpreted as the result of a reactive control mechanism. Specifically, when conflict is detected (i.e., on incongruent trials) a reactive control mechanism is recruited to implement control. If the preceding trial was also incongruent, the control mechanism would have already been engaged, and there is no need for reactivation, resulting in relatively efficient performance for incongruent-incongruent (iI) transitions (Botvinick, et al., 2001). By contrast, PC effects are often attributed to the adoption of a sustained or proactive strategy or task set, probably implemented after having experienced the level of conflict encountered on the first few trials in a block. This task set is assumed to produce tonic changes in processing by, for example, altering the 'weighting' of word-reading relative to color-naming (e.g. Cohen, Dunbar, & McClelland, 1990).

The Dual Model of Cognitive Control recently proposed by Braver and colleagues (Braver, Gray, & Burgess, 2007; DePisapia & Braver, 2006), is consistent with that view of SC effect as reactive control and PC effects as proactive control. This model suggests that cognitive control consists of at least two sub-systems: a reactive mechanism that is recruited only when needed, that is, once interference is detected, and a second mechanism characterized by the sustained active maintenance of task-set information, allowing the anticipation and prevention of interference before it occurs. Although our results do not clarify the nature of the mechanism underlying both SC and PC effects, they support the existence of several control mechanisms.

No matter whether we entertain the cognitive control account of SC and PC effects presented here, or other different approaches based on memory and learning processes (for a review see Bugg & Crump, 2012; Schmidt, in press), it is important to highlight the critical contribution of the present results: regardless of the nature of the underlying mechanism, PC effects cannot be fully explained by the same mechanism that accounts for SC effects. Therefore, previous approaches suggesting that PC effects are fully explained by SC effects need to be revised. Future research should keep in mind that there can be some PC effects that are a by-product of the accumulation of SC effects, but they are other PC effects that are not, and therefore must be different in nature.

In summary, the present experiment show that proportion congruent effects are observed in the absent of sequential congruency effects, suggesting that different mechanisms must underlie the two effects. We believe that cognitive control theories can account for the present findings but we do not deny that other learning and memory-based mechanisms can also contribute to the explanation of the same data. Therefore, more research is needed to understand the contribution of each mechanism to sequential congruency and proportion congruent effects.

RESUMEN

Efectos de proporción de congruencia en ausencia de efectos secuenciales de conflicto. En el campo del control cognitivo, una pregunta de gran interés es si el control cognitivo está formado por uno o varios mecanismos. Una forma de responder a esta pregunta ha sido la disociación de dos efectos relacionados con control cognitivo: los efectos secuenciales y los efectos de proporción de congruencia. De forma similar, este experimento tiene como objetivo disociar ambos efectos pero en este caso investigando si los efectos de proporción de congruencia se producen en ausencia de los efectos secuenciales. Para ello se presentaron dos tipos de conflicto mezclados aleatoriamente (Simon y Stroop Espacial) y con la proporción de congruencia manipulada en uno de ellos, manteniendo neutral el número de ensayos congruentes e incongruentes en el otro conflicto. Nuestros resultados mostraron que en los ensayos en los que se producía una alternancia de tipo de conflicto, y dónde los efectos secuenciales estaban ausentes, se observaron efectos de proporción de congruencia. Esto indica que, al menos en circunstancias concretas, los efectos de proporción de congruencia y secuenciales son independientes y específicos al tipo de conflicto.

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