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Different mechanisms can account for the instruction induced proportion congruency effect

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A B S T R A C T

When performing a conflict task, performance is typically worse on trials with conflict between two responses (i.e., incongruent trials) compared to when there is no conflict (i.e., congruent trials), a finding known as the congruency effect. The congruency effect is reduced when the proportion of incongruent trials is high, relative to when most of the trials are congruent (i.e., the proportion congruency effect). In the current work, it was tested whether different kinds of instructions can be used to induce a proportion congruency effect, while holding the actual proportion of congruent trials constant. Participants were instructed to strategically use the (invalid) information that most of the trials would be congruent versus incongruent, or they were told to adopt a liberal versus a conservative response threshold. All strategies effectively altered the size of the congruency effect relative to baseline, although in terms of statistical significance the effect was mostly limited to the error rates. A diffusion-model analysis of the data was partially consistent with the hypothesis that both types of instructions induced a proportion congruency effect by means of different underlying mechanisms.

1. Introduction

Cognitive control refers to the cognitive and neural mechanisms to deal with information that interferes with our plans and goals (Botvinick, Braver, Barch, Carter, & Cohen, 2001; Verguts & Notebaert, 2009). For example, when a continental European drives a car in the United Kingdom, cognitive control mechanisms are needed to overrule the tendency to operate the traffic indicator with the left hand, thereby avoid hitting the wipers at every turn. One of the most influential approaches to experimentally study cognitive control, is to examine how humans adapt their behavior in the face of response conflict. This can be studied in conflict tasks where conflict is experimentally induced between two incompatible responses. For example, in the Simon task participants might be instructed to respond with the left hand to green stimuli and with the right hand to red stimuli, while ignoring the location where stimuli are presented (i.e., left or right from fixation; Simon & Rudell, 1967). Despite the instruction to ignore the location, reaction times are longer and error rates higher when the location of the stimulus is different from the response required by the color of the stimulus (i.e., when there is response conflict; incongruent trials), compared to when both trigger the same response (i.e., congruent trials). Thus, cognitive control mechanisms are required in this task to prevent oneself from responding to the location, and instead direct attention to the color. By varying the proportion of incongruent trials, it is possible to create conditions that differ in the need for cognitive control. When the majority of trials are incongruent, compared to congruent, the congruency effect is reduced, a finding known as the *proportion congruency effect* (Logan & Zbrodoff, 1979). This is one of the hallmark observations assumed to reflect an increase in cognitive control (e.g., Aben, Verguts, & Van den Bussche, 2017; Abrahamse, Duthoo, Notebaert, & Risko, 2013; Funes, Lupiáñez, & Humphreys, 2010).

The dominant interpretation of this effect is in terms of *conflict adaptation* (Botvinick, 2007; Botvinick et al., 2001). When conflict is detected between two responses, participants direct attention away from the irrelevant dimension. When most of the trials are incongruent (i.e., *mostly incongruent*), a sustained level of cognitive control is needed to suppress the location information. This is beneficial for incongruent trials, but it reduces the facilitative effect of location on the infrequent congruent trials, leading to reduced congruency effects. When the majority of trials are congruent (i.e., *mostly congruent*), a transient increase in cognitive control is sufficient to deal with the infrequent occurrence of response conflict. This strategy works well for congruent trials, but not for the few incongruent trials, and as a consequence the

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congruency effect will be large. This interpretation of the proportion congruency effect has recently been challenged. In particular, it has been argued that the effect might also be explained by contingency learning or episodic memory confounds (Schmidt & Besner, 2008). In a list with mostly incongruent trials, performance is better on incongruent trials and worse on congruent trials, compared to performance in a list with an equal number of both trials. However, the former list also contains much more incongruent trials overall, so performance on these trials might be better because participants are more frequently exposed to incongruent trials (Schmidt & Besner, 2008). More specifically, in a mostly incongruent block using the Simon task, stimuli appearing on the left are predictive of right hand responses, and vice versa.

In the current work, contingency learning and episodic memory confounds will be overcome by keeping the amount of response conflict constant, and instead manipulate participants' strategy. Previous work has already demonstrated that instructions might be sufficient to induce a proportion congruency effect (e.g., Bugg, Diede, Cohen-shikora, & Selmeczy, 2015; Bugg & Smallwood, 2016; Entel, Tzelgov, & Bereby-Meyer, 2014; Wühr & Kunde, 2008). However, the precise mechanisms by which participants implemented these instructions remain unclear. For example, in Entel et al. (2014), participants were informed that most of the trials would be congruent (or incongruent; depending on the group), but it was not explained how participants were to implement these instructions (the same is true for Bugg & Smallwood, 2016). Typically, it is assumed in such experiments that participants allocate attention to the relevant information depending on the proportion of congruent trials (Bugg & Smallwood, 2016; Wühr & Kunde, 2008). It could also be, however, that participants reasoned that a block with mostly congruent trials will be very easy, and thus that they could respond rapidly without the risk of making many errors. Under this scenario, instead of strategically allocating attention, participants adopt a liberal response threshold, providing a response with only a minimum of accumulated information. The counterpart of this strategy is that participants adopt a conservative response threshold (i.e., increased response caution), when they expect mostly incongruent trials. It has been shown that changes in the trade-off between speed and accuracy can indeed influence the size of the congruency effect (van Veen, Krug, & Carter, 2008). Given that strategically allocating attention and balancing between speed and accuracy are entirely different mechanisms, it is important to unravel whether both strategies can indeed be used to induce a proportion congruency effect. Moreover, it is crucial to demonstrate that both strategies induce a proportion congruency effect by means of different underlying mechanisms.

Although strategically allocating attention and balancing between speed and accuracy are different strategies, they are difficult to dissociate because both make similar behavioral predictions (i.e., a proportion congruency effect). Using cognitive modelling it might be possible to examine the underlying mechanisms of both strategies (Voss, Nagler, & Lerche, 2013). A rich literature exists explaining two-choice decisions as resulting from the accumulation of evidence for both response options (Gold & Shadlen, 2007). In the drift-diffusion model, it is assumed that the decision whether perceptual input belongs to either of two categories is done by comparing the evidence accumulated in favor of each alternative (Ratcliff & McKoon, 2008). Once the difference in accumulated evidence reaches a threshold, a decision will be made. The model has separate parameters for the rate of evidence accumulation (i.e., the drift rate), the amount of evidence that is required before a decision is made (i.e., the decision bound), and for non-decision related processing (non-decision time). Interestingly, each of the two strategies discussed above can be linked to one of the parameters in the model. Increasing attention to the color (i.e., the relevant information) will increase the speed with which colors are processed (i.e., the drift rate), but not necessarily change the amount of evidence required to select a response (i.e., the decision bound). Thus, when participants expect most of the trials to be congruent, drift rates should be high when they encounter a congruent trial (i.e., fast accumulation of evidence; an easy trial) and low when they encounter an incongruent trial (i.e., slow accumulation of evidence; a difficult trial). When participants expect most of the trials to be incongruent, the reverse should be true. Importantly, whether participants expect mostly congruent or mostly incongruent trials should leave the decision bound unaffected. The decision bound should, however, be affected by the instructions to balance speed and accuracy. Trading speed for accuracy results in an elevated decision bound, while leaving the drift rate unaffected (Forstmann et al., 2008). Thus, drift-diffusion model analysis of the data might help to shed light on different underlying mechanisms of behaviorally indistinguishable proportion congruency effects.

2. Experiment

1. Method

1. Participants

Twenty-five participants (four males, mean age: 20.6 years, *SD* = 3.4, range 18–33) took part in the experiment. Participants provided written informed consent before participation, and were awarded course credit. All reported normal or corrected-to-normal vision and were naive with respect to the hypothesis.

2. Stimuli and apparatus

The experiment was programmed in *E*-prime for Windows (Psychology Software Tools, Pittsburgh, PA) and run on Intel Pentium 4 computers with 17 in. LCD screens. The refresh rate was set to 60 Hz. Targets were four color patches (3.5° wide and 3.5° high) in blue (RGB 0, 0, 255), yellow (RGB 255, 242, 0), green (RGB 34, 177, 76) or orange (RGB 255, 127, 39), presented on a black background. Responses were executed on Cedrus response boxes (type RB-840).

3. Procedure

Participants were instructed to respond with the left index finger to blue and yellow patches and with the right index finger to green and orange patches (reversed for half of the participants). Patches were presented at the left or right side of the screen (at 9.7°). Each trial started with a white fixation cross for 500 ms, followed by the color patch, which was presented until a response was made. The inter-trial interval (ITI) lasted 1000 ms. Each block contained an equal number of congruent and incongruent trials.

The experiment started with sixteen practice trials where feedback was presented during the ITI when participants made an error. Afterwards, each participant performed five blocks of eighty trials, without feedback. The first of these five blocks was a baseline block, where participants were instructed to respond as fast and accurate as possible. Next, four otherwise identical blocks were administered that were preceded by different instructions. In Table 1, a translation of the different instructions can be found. In the speed/accuracy instruction blocks, the instructions stressed either speed (i.e., promoting a liberal response threshold) or accuracy (i.e., promoting a conservative response threshold). In the allocation of attention instruction blocks, the instructions stressed that most of the trials would be congruent or most of the trials would be incongruent, and participants were told to strategically use the irrelevant location information depending on the proportion of congruent trials. The order of the four instructions conditions was fully counterbalanced, with the exception that the liberal and conservative instruction conditions and the mostly congruent and mostly incongruent instruction conditions were always presented in adjacent blocks.