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Now you see it, now you don't: Controlling for contingencies and stimulus repetitions eliminates the Gratton effect ☆

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ABSTRACT

The Gratton (or sequential congruency) effect is the finding that conflict effects (e.g., Stroop and Eriksen flanker effects) are larger following congruent trials relative to incongruent trials. The standard account given for this is that a cognitive control mechanism detects conflict when it occurs and adapts to this conflict on the following trial. Others, however, have questioned the conflict adaptation account and suggested that sequential biases might account for the Gratton effect. In two experiments, contingency biases were removed from the task and stimulus repetitions were deleted to control for stimulus bindings. This eliminated the Gratton effect in the response times in both experiments, supporting a non-conflict explanation of the Gratton effect. A Gratton effect did persist in the errors of Experiment 1; however, this effect was not produced by the type of errors (word reading errors) that a conflict adaptation account should predict. Instead, tentative support was found for a congruency switch cost hypothesis. In all, the conflict adaptation account failed to account for any of the reported data. Implications for future work on cognitive control are discussed.

Learning processes mould behaviour via knowledge about the contingency between (Lewicki, 1985, 1986; Schmidt, submitted for publication; Schmidt & Besner, 2008; Schmidt, Crump, Cheesman, & Besner, 2007; Schmidt, De Houwer, & Besner, 2010) or sequence of (Hommel, 1998; Nissen & Bullemer, 1987) events we encounter in our environment. The role of cognitive control processes on our performance and behaviour has also been intensely studied in cognitive psychology (e.g., Botvinick, Braver, Barch, Carter, & Cohen, 2001; Cohen, Dunbar, & McClelland, 1990; Cohen & Hudson, 1994; Norman & Shallice, 1986; Rabbitt, 1966). Often debate can be quite heated as to whether a given result reported in the literature is due to learning processes, cognitive control processes, or some combination of the two (e.g., see Blais & Bunge, 2010; Schmidt, submitted for publication). One such result is the Gratton effect. Initially proposed as a cognitive control effect (Gratton, Coles, & Donchin, 1992), several researchers have challenged this view (e.g., Mayr & Awh, 2009; Mayr, Awh, & Laurey, 2003). This paper will present what we feel to be clear evidence that the Gratton effect results from non-conflict task biases (primarily contingency and stimulus repetition biases).

1. Stimulus conflict and cognitive control

Several paradigms exist for studying stimulus conflict. One of these is the Stroop task (Stroop, 1935; see MacLeod, 1991, for a review), in which participants typically respond slower and less accurately to the print colour of a colour word if the word and colour are incongruent (e.g., the word GREEN printed in blue; $\text{GREEN}_{\text{blue}}$) rather than congruent (e.g., $\text{BLUE}_{\text{blue}}$). Similar congruency effects are observed in the Simon task (Simon & Rudell, 1967), where an irrelevant distracting location (e.g., left) interferes with a localised response (e.g., a right key press). Yet another paradigm is the Eriksen flanker task (Eriksen & Eriksen, 1974), where irrelevant flanking letters interfere with responding to a target letter (e.g., a distracting "b" to the left and the right of a target "c"). Work with paradigms such as these demonstrates that unintentional processing of distracting information has an important impact on performance in the intended task.

While the impact of unintentional processes on behaviour in stimulus conflict tasks is unequivocal, many researchers are interested in the role of controlled behaviour on moderating performance in these tasks. One effect studied in this regard is the Gratton effect. The Gratton effect is the finding that congruency effects are larger following congruent relative to incongruent trials. This effect was first observed in the Eriksen flanker task by Gratton et al. (1992), but

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has also been observed in other tasks such as the Stroop task (e.g., Mayr & Awh, 2009; Notebaert, Gevers, Verbruggen, & Liefooghe, 2006). The standard account of the Gratton effect, termed the *conflict adaptation account*, is that participants detect conflict on incongruent trials and decrease attention to the word on the following trial in order to avoid further conflict. As a result, the Stroop effect will be smaller. In contrast, on congruent trials there is no conflict, so attention will not be as constrained on the following trial. Hence, the word can interfere more strongly and the Stroop effect will be larger. Due to these processes, a Gratton effect will emerge, that is, an interaction between congruency on the current trial and congruency on the previous trial ($n-1$ congruency). As will be discussed in the following section, although by far the most popular account of the Gratton effect, the conflict adaptation account has not gone unchallenged.

2. Stimulus binding biases

There are a whole series of confounds present in standard Stroop paradigms that can lead towards an interaction between congruency and $n-1$ congruency in the absence of conflict adaptation. Essentially all of these confounds bias the interaction in the same direction, that is, in the direction of a Gratton effect. Several of them have already been studied. The first one is related to stimulus binding effects. Hommel (1998) observed that participants respond more quickly to trials in which both the distracting and target stimulus dimensions alternate (e.g., BLUE_{red} followed by $\text{GREEN}_{\text{yellow}}$; $\text{BLUE}_{\text{red}} \rightarrow \text{GREEN}_{\text{yellow}}$) or both repeat (e.g., $\text{BLUE}_{\text{red}} \rightarrow \text{BLUE}_{\text{red}}$) relative to when one, but not both of the stimulus dimensions repeat (e.g., $\text{BLUE}_{\text{red}} \rightarrow \text{BLUE}_{\text{yellow}}$ or $\text{BLUE}_{\text{red}} \rightarrow \text{GREEN}_{\text{red}}$). The claimed reason for the impairment of performance on these partial repetition trials is that repetition of one stimulus dimension (e.g., the word) leads to retrieval of the previous binding (e.g., BLUE_{red}), which conflicts with the processing of the current stimulus (e.g., $\text{BLUE}_{\text{yellow}}$).

Mayr et al. (2003) pointed out that stimulus repetitions, alternations, and partial repetitions are not equally prevalent in the four crucial conditions used for assessing the Gratton effect. They found that after analysing alternation trials only (i.e., trials in which both the word and colour change), the Gratton effect disappeared. Subsequently, however, other work has demonstrated that Gratton effects, though weakened, can be observed even after word–word and colour–colour repetitions are removed (Freitas, Bahar, Yang, & Bahar, 2007; Kerns et al., 2004; Notebaert et al., 2006). Further work has also removed word–colour repetitions (i.e., negative priming trials; e.g., $\text{BLUE}_{\text{red}} \rightarrow \text{GREEN}_{\text{blue}}$) and colour–word repetitions ($\text{BLUE}_{\text{red}} \rightarrow \text{RED}_{\text{yellow}}$), with results again showing a reduction but not elimination of the Gratton effect (Akçay & Hazeltine, 2007; Verbruggen, Notebaert, Liefooghe, & Vandierendonck, 2006).

3. Sequential contingency biases

Contingency biases (Schmidt, in press) are a second confound that have been shown to artificially elevate the size of the Gratton effect. Experimenters often present distracting colour words more often in their congruent colour than would be expected by chance. For instance, in a four-choice task BLUE might be presented in blue 50% of the time, where chance would be 25%. This is problematic because Schmidt et al. (2007) have shown that participants learn these contingencies and respond faster and more accurately to high contingency trials (i.e., where the word is presented in its most frequent colour) relative to low contingency trials (i.e., where the word is presented in an unexpected colour). If words are presented most often in their congruent colours, then congruency and contingency are perfectly confounded: congruent trials are high contingency and incongruent trials are low contingency. This is also true on the preceding ($n-1$) trial: $n-1$ congruent trials are high contingency and $n-1$ incongruent trials are low contingency. Schmidt and colleagues have further shown that *contingency* and $n-1$ *contingency* (i.e., contingency on the previous trial) interact. Specifically, the contingency effect (low contingency–high contingency) is larger following high contingency trials than following low contingency trials. Thus, Gratton experiments with contingency confounds will be biased by a sequential contingency effect.

There are several possible reasons why a sequential contingency effect might occur. One account, superficially similar to the conflict adaptation account, is that participants increase attention to the word following a correct response prediction. The word correctly predicts the response on high contingency trails (e.g., for $\text{BLUE}_{\text{blue}}$, where BLUE is presented most often in blue), thus leading to more attention to the word on the following trial, making for a larger contingency effect. In contrast, the word does not correctly predict the response on low contingency trials (e.g., for BLUE_{red}), thus leading to less attention to the word on the following trial, making for a smaller contingency effect. Note that the attentional modulation component of this account is only superficially similar to the conflict adaptation account, as the system is proposed to shift attention based on response expectancy and not based on conflict (i.e., congruency).

Another, non-attentional explanation for the sequential contingency effect could be stimulus sequence biases. Participants respond faster to predictable sequences of trials (Nissen & Bullemer, 1987) and participants will see a sequence of any two given high contingency trials more frequently than a series of any two given low contingency trials. For instance, because the high contingency trials $\text{BLUE}_{\text{blue}}$ and $\text{GREEN}_{\text{green}}$ are presented quite frequently, participants will very often see the sequence $\text{BLUE}_{\text{blue}} \rightarrow \text{GREEN}_{\text{green}}$. In contrast, they will much less frequently see a sequence such as $\text{BLUE}_{\text{red}} \rightarrow \text{GREEN}_{\text{green}}$ or $\text{GREEN}_{\text{green}} \rightarrow \text{BLUE}_{\text{red}}$, given that the stimulus BLUE_{red} appears only infrequently. Indeed, such sequences violate the expectation of the stimuli likely to follow or precede a given high contingency trial (i.e., $\text{GREEN}_{\text{green}}$ is not expected to go with BLUE_{red}). Thus, (high contingency) congruent trials will be faster if preceded by a (high contingency) congruent trial rather than a (low contingency) incongruent trial. Similarly, a (low contingency) incongruent trial will be impaired if preceded by a (high contingency) congruent trial relative to a (low contingency) incongruent trial.[1]

Regardless of what the mechanism is driving the sequential contingency effect, it has been demonstrated by Schmidt et al. (2007). Thus, the smaller Stroop effect following (low contingency) incongruent trials relative to (high contingency) congruent trials may be in part a result of a sequential contingency effect rather than a sequential congruency effect.

Further support for the idea that contingency biases contribute to the Gratton effect comes from a study by Mayr and Awh (2009) who varied the proportion of congruent to incongruent trials from 70% to 30% in a six-choice task. Reducing the proportion of congruent trials reduces contingency biases and this manipulation reduced the Gratton effect. However, it did not explain the whole effect: a (reduced) Gratton effect was still present, even after deleting stimulus repetitions in the 30% condition. We do note, however, that 30% congruent items in a six-choice task is still well above chance (16.7%), thus not eliminating all contingency biases. Some studies do present congruent trials no more often than expected by chance, particularly in two-choice tasks (e.g., Davelaar & Stevens, 2009). However, these studies do not control for stimulus bindings (and cannot do so with a two-choice task). Nieuwenhuis et al. (2006) were able to control for response repetitions, however, and this eliminated the Gratton effect in their contingency-unbiased two-choice experiments. Although they were unable to control for partial stimulus repetitions due to the two-choice nature of the tasks, their results are encouraging for the idea that the Gratton effect is due to sequential confounds rather than conflict adaptation.

[1] All (low contingency) incongruent items are presented infrequently, so a series of two of them does not violate any sequential trial biases.