



# Event-related potentials as brain correlates of item specific proportion congruent effects



Judith M. Shedden\*, Bruce Milliken, Scott Watter, Sandra Monteiro

Department of Psychology, Neuroscience and Behaviour, McMaster University, Canada

## ARTICLE INFO

### Article history:

Received 22 July 2013

Available online 26 October 2013

### Keywords:

Attention

Event-related potentials

ERP

Item-specific proportion congruent

ISPC

Automatic control

Context effects

P1

Control processes

## ABSTRACT

The item-specific proportion congruency (ISPC) effect is consistent with the idea that control processes can be applied rapidly in accord with previously experienced conflict for a particular category. An alternative account of this effect is that it reflects item-specific learning processes unrelated to control at the level of the category. The accounts predict the same behaviour but differ in terms of electrophysiological predictions. Two experiments examined the ISPC effect with a particular focus on neural correlates that might reveal whether, and how early in processing, high and low proportion congruent items are treated as distinct classes of stimuli. For both tasks, the proportion congruency category was distinguished prior to the congruence of the specific stimulus, as early as 100 ms post-stimulus onset for the global/local identification task (Experiment 1) and 150 ms for the Stroop task (Experiment 2). The results support an on-line control account of ISPC effects.

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## 1. Introduction

The distinction between automatic and controlled processes has a long history in cognitive psychology. The dual process model that emerged in the 1970s, and that remains influential today, assumes that strongly automatic processes are fast, resource free, ballistic, and can occur in the absence of awareness of stimuli that elicit them. In contrast, cognitive control is thought to involve processes that are slow to initiate, resource demanding, subject to volition, and open to conscious inspection. This distinction has been illustrated in many types of attention and performance tasks, including Stroop (Stroop, 1935) and other Stroop-like tasks (Logan & Zbrodoff, 1979), visual search (Schneider & Shiffrin, 1977; Shiffrin & Schneider, 1977), same-different matching (Posner & Snyder, 1975), and attentional cuing (Jonides, 1981), and also in a host of higher-order cognition domains (Jacoby, Toth, & Yonelinas, 1993).

In this article, we focus on a recent finding that appears to blur the distinction between automatic and controlled processes. In particular, our focus is a result reported by Jacoby, Lindsay, and Hessels (2003), which they referred to as an item-specific proportion congruent (ISPC) effect in the Stroop task. This effect is noteworthy because it appears to be a cognitive control effect that does not fit the conventional definition of controlled processes offered above. The present study examines the ISPC effect in both a global–local interference task and a Stroop interference task, with a particular focus on event-related potential (ERP) correlates of the effect. As will become evident, ERP correlates of the ISPC effect prove helpful in distinguishing among the potential implications of this effect for theories of cognitive control.

\* Corresponding author. Address: Department of Psychology, Neuroscience and Behaviour, McMaster University, Hamilton, Ontario L8S 4K1, Canada.  
E-mail addresses: [shedden@mcmaster.ca](mailto:shedden@mcmaster.ca), [judith.shedden@gmail.com](mailto:judith.shedden@gmail.com) (J.M. Shedden).

### 1.1. The item-specific proportion congruent effect

Although it has long been known that the magnitude of Stroop interference depends on the proportion of congruent (word and colour match) trials within a block (Logan & Zbrodoff, 1979; Logan, Zbrodoff, & Williamson, 1984; Lowe & Mitterer, 1982; Tzelgov, Henik, & Berger, 1992), such demonstrations typically come from studies in which proportion congruent is manipulated either between blocks of trials, or between-subjects. When proportion congruent is varied in this manner, it is reasonable to conclude that participants evaluate the task context, discover that either many or few of the trials are congruent, and then adjust their task strategy accordingly. For example, when many of the trials are congruent, participants might adopt the strategy of reading the word despite the overt task requirement of naming the colour, as word reading is relatively fast and rarely affords an incorrect response. In contrast, when few of the trials are congruent, participants would be more likely to adopt a strategy that prevents word reading from occurring, as word reading more often than not leads response selection astray. The important point to note is that these adjustments in task strategy can easily be attributed to changes in rather slow, deliberate control processes that are set in response to an evaluation of the task context.

The ISPC effect reported by Jacoby et al. (2003) is noteworthy because it is not easily explained by such list-wide adjustments in task strategy. In the study by Jacoby et al., two categories of Stroop items were created, one of which was designated 'mostly congruent' while the other was designated 'mostly incongruent.' For example, the word RED might often appear in the colour red and rarely in the colour green (a mostly congruent item) whereas the word BLUE might often appear in the colour yellow and rarely in the colour blue (a mostly incongruent item). These two types of items were mixed at random within the experimental session, ensuring that participants could not predict the operative likelihood of congruency prior to stimulus onset. Despite the unpredictability of the item sets, the Stroop effect was larger for the mostly congruent items than for the mostly incongruent items. This result is not easily explained by reference to list-wide changes in task strategy, but is consistent with the view that processing of the distracting word can be controlled rapidly upon stimulus onset. Jacoby et al. referred to these on-line adjustments in word reading as 'automatic control'. Similar on-line control effects have now been reported for a range of Stroop-like effects (Bugg, Jacoby, & Toth, 2008; Crump, Vaquero, & Milliken, 2008; for reviews see Bugg, 2012; Bugg & Crump, 2012), as well as flanker effects (Cañadas, Rodríguez-Bailón, Milliken, & Lupiáñez, 2012; Corballis & Gratton, 2003; Lehle & Hübner, 2008; Vietze & Wendt, 2009; Wendt & Kiesel, 2011; Wendt, Kluwe, & Vietze, 2008), masked-priming effects (Heinemann, Kunde, & Kiesel, 2009) and task switching effects (Leboe, Wong, Crump, & Stobbe, 2008).

### 1.2. 'Automatic control' versus contingency and item frequency accounts

The ISPC effect has potentially interesting implications for the study of cognitive control. In particular, the ISPC effect suggests that appropriate ways of encoding and responding to stimuli are learned through experience, and can be retrieved rapidly during on-line performance. At first blush, this proposal may appear redundant with an instance theory of automaticity (Logan, 1988). However, a proposal unique from instance theory can be carved out by focusing on the retrieval of somewhat abstract control procedures that are appropriate for an item type, rather than the retrieval of specific encoding operations for a prior instance that matches perfectly with the current target. Grounding this distinction in an example may make it more clear. If the word RED usually appears in red and rarely appears in green, the idea is that onset of the word RED will cue word reading processes generally, rather than word reading processes associated with any particular instance in which the word RED was coloured red or green. By this view, a large Stroop interference effect that occurs for mostly congruent items owes to an increased contribution to performance of word reading processes that are appropriate for the word RED in red, but inappropriate for the word RED in green.

Yet, it must be noted that there is more than one way to account for the ISPC effect. As Jacoby et al. (2003) noted, rather than rapid on-line adjustments in control, the ISPC effect could result from rather simple associative learning processes. For example, if the word RED usually appears in red and rarely appears in green, then a stronger intra-experimental association might form between the word RED and the response red than between the word RED and the response green. This association might then magnify the Stroop effect. In contrast, if the word BLUE usually appears in yellow and rarely appears in blue, a relatively strong association between the word BLUE and the response yellow would shrink the Stroop effect. Together, this pattern of results would constitute an ISPC effect, but it would not require any novel inferences about on-line control.

On a similar theme, if one assumes nothing more than that speed of performance for an item depends on the frequency with which that item is presented within an experimental session, the ISPC effect is perfectly consistent with power law based learning processes that are specific to particular items (Logan, 1988). For example, if the word RED in green is presented 80 times within an experimental session, instance theory would predict that it would be responded to more quickly than if that same item were presented only 20 times within an experimental session. Therefore each presentation of the word RED would rapidly retrieve the response green. Relatively small Stroop interference effects for mostly incongruent items might therefore result from learning processes that are specific to particular items rather than forming the basis for rapid and generalized shifts in cognitive control for classes of items.

Indeed, Schmidt and Besner (2008) reported a set of results supportive of the idea that ISPC effects in Stroop colour naming reflect the learning of contingencies between words and responses, rather than on-line adjustments in control over word reading. For example, they pointed out that when the word RED appears in green on 80% of the trials while the word RED appears in RED on 20% of the trials, the word RED is more likely to cue the response 'green' than the response 'red',

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