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List-level transfer effects in temporal learning: Further complications for the list-level proportion congruent effect

James R. Schmidt

Department of Experimental Clinical and Health Psychology, Ghent University, Henri Dunantlaan 2, B-9000 Ghent, Belgium

Congruency effects are larger when most trials are congruent relative to incongruent. According to the conflict adaptation account, this proportion congruent effect is due to the decreased attention to words when most of the trials are conflicting. This paper extends on previous work arguing that list-level (contingency-unbiased) proportion congruent effects might be explainable by temporal learning biases. That is, congruency effects are larger in an easier task (i.e., mostly congruent) due to the faster pace of the task. Two non-conflict analogues of the proportion congruent effect are presented, one with a contrast manipulation and another with a contingency manipulation. Critically, both experiments control for potential item-specific temporal learning biases by intermixing biased context and unbiased transfer items. Results show a proportion congruent-like interaction for both item types, supporting the notion of task-wide temporal learning as an explanation for list-level proportion congruency effects. Distributional analyses lend further credence to the temporal learning account by showing that proportion congruent and proportion congruent-like effects are localised in the fastest and intermediate responses.

Keywords*:* Conflict adaptation; Contingency learning; Contrast; Delta plot; Distributional analyses; Proportion congruent; Temporal learning; Transfer.

In the cognitive control literature, the conflict adaptation account proposes that participants adjust their attentional allocation to stimulus features in response to conflict. One proposed example of this is the proportion congruent effect (Lowe & Mitterer, 1982). In the Stroop (1935) task, for instance, participants respond to the print colour of a coloured word, and responses are slower and less accurate when the word and colour are incongruent (e.g., the word "red" printed green; red_{green}), relative to when they are congruent (e.g., red_{red}). This congruency effect is larger when most of the trials in the task are congruent (mostly congruent), relative to when most of the trials are incongruent (mostly incongruent). According to the conflict adaptation account (e.g., Botvinick, Braver, Barch, Carter, & Cohen, 2001), this "proportion congruent" effect results from participants reducing attention to the word in the mostly incongruent condition in order to reduce further conflict. In contrast, relatively more attention to the word is allowed in the mostly congruent condition, where conflict is less frequent.

However, there are some who argue that conflict adaptation may be the incorrect interpretation of the proportion congruent effect (for a review, see Schmidt, 2013a). For instance, most of

Correspondence should be addressed to James R. Schmidt, Department of Experimental Clinical and Health Psychology, Ghent University, Henri Dunantlaan 2, B-9000 Ghent, Belgium. E-mail: james.schmidt@ugent.be

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the effect seems to be driven by item-specific biases (e.g., Blais & Bunge, 2010; Bugg, Jacoby, & Toth, 2008; Jacoby, Lindsay, & Hessels, 2003), and some argue that the effect might be entirely driven by non-conflict contingency learning biases (e.g., Schmidt, 2013c; Schmidt & Besner, 2008; see also Mordkoff, 1996). However, there is also a small list-level proportion congruent effect that cannot be explained by item-specific biases. For instance, Hutchison (2011; see also, Bugg, McDaniel, Scullin, & Braver, 2011) manipulated some, but not all, items for proportion congruency. For instance, the *context items* green and white were presented most often congruently for some participants and most often incongruently for other participants. Other *transfer items*, such as blue and red, were presented with the equivalent frequencies for participants presented with mostly congruent and mostly incongruent lists.[1] In this way, the context items set the proportion congruency for the task, whereas the intermixed transfer items have no systematic biases across the two proportion congruent lists. Hutchison's observation of a proportion congruent effect for transfer items can thus be described as a list-level effect: the proportion congruent effect for these items cannot be explained by biases in the items themselves.

This list-level proportion congruent effect seems to suggest that conflict adaptation can occur at the task-wide (i.e., list) level. However, there might be further complications. Although item-specific biases are controlled for in the list-level preparation, Schmidt (2013a, 2013b) pointed to another bias, namely, temporal learning. It is well known in the temporal learning literature that the speed of responding to previous trials has large influences on the current trial (e.g., Kinoshita, Forster, & Mozer, 2008; Kinoshita, Mozer, & Forster, 2011). Of particular importance, Kinoshita et al. (2011) showed that the faster the response time (RT) was on the preceding trial, the larger the congruency effect. Controlling for this effect of previous RTs greatly reduces the standard proportion congruent effect. This was with the standard paradigm, which is contingency-biased. However, Schmidt (2013b) further showed that the list-level (i.e., contingency-unbiased) proportion congruent effect is also reduced by controlling for previous RTs. There are several potential explanations for such effects of previous RTs. For instance, the adaptation to the statistics of the environment (ASE) account discussed in the Kinoshita et al.'s (2008, 2011) work suggests that, in order to balance speed and accuracy, the response threshold is adjusted differently in easier (e.g., mostly congruent) and harder (e.g., mostly incongruent) tasks (see Mozer, Colagrosso, & Huber, 2002), and easier (e.g., congruent) trials are more affected by this shift.

Alternatively, an episodic account by Schmidt (2013b) proposes that each trial is stored as an episodic memory, which contains information about the stimuli presented, the response given, and, more critically, the time it took to respond (i.e., RT). On subsequent trials, information about the RTs of recently stored episodes is retrieved, and this RT information is used to anticipate when a response will be available on the current trial. Concretely, the parallel episodic processing (PEP) computational model presented by Schmidt retrieves episodes and decreases the global response threshold dynamically during the course of the trial. The threshold is decreased the most at moments that closely correspond to the RTs given on previous trials. A (simplified) illustration of this is given in Figure 1. Because most of the previous responses will have been fast in the mostly congruent list, a (temporary) drop in the response threshold with occur early in the trial. This will tend to benefit congruent trials, which will be active enough to cross this reduced threshold. However, incongruent trials will tend to accrue response activation too slowly to benefit; the response threshold will have already gone back up to normal. The net result is a large congruency effect. In the mostly incongruent list, the reverse is true. Most responses will be slow, biasing a drop in the response threshold later in the trial. This will benefit incongruent trials, because the response threshold will decrease around the time when activation is high enough to cross it. Congruent trials will not benefit, because the response will have been made even before the threshold drops. Thus, the congruency effect will be small.

Of course, the PEP and ASE models are just two variants of a temporal learning account, and it is not the goal of the present work to distinguish between the two. Whatever the mechanism driving temporal learning, it is clear that previous RTs not only strongly correlate with current RTs, but also have an effect on various manipulations of difficulty, such as the congruency effect. Temporal learning is entirely different than conflict

[1] Note that the transfer items did have an item-specific manipulation. However, the manipulation for transfer items was identical in the mostly congruent and mostly incongruent lists. Thus, any item-specific biases were equated.

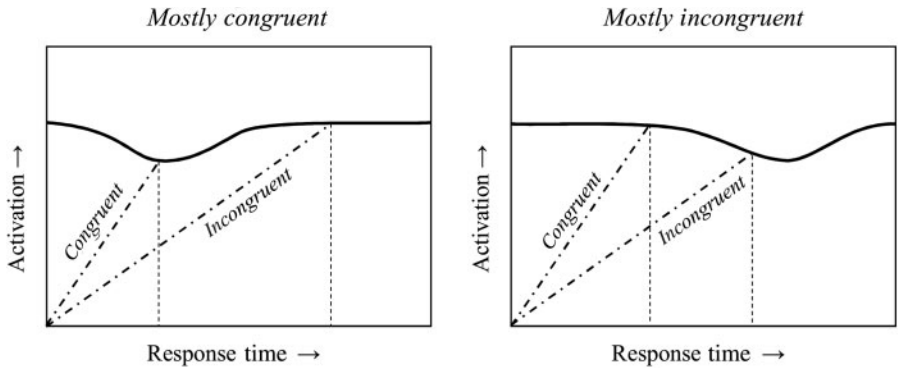

Figure 1. Example of temporal expectancies reflected through drops in the response threshold (thick black line) in a mostly congruent (fast) and mostly incongruent (slow) context.

adaptation, because participants adjust their expectancies in response to temporal information (i.e., when to respond) rather than adjusting attention in response to conflict. Schmidt (2013b) further showed that such temporal learning is not at all dependent on conflict. Instead of using distracters and conflict to manipulate congruency, Schmidt manipulated contrast. Specifically, target letters were either *high contrast* (easy to see) or *low contrast* (hard to see). This produces faster responses for high relative to low-contrast trials, termed a contrast effect. In place of proportion congruency, *proportion easy* was manipulated such that most of the trials were either high contrast (mostly easy) or low contrast (mostly hard). A proportion easy effect was observed in that the contrast effect was larger in the mostly easy relative to mostly hard list. Note that this is similar to a proportion congruent effect, except that there was no distracting stimulus, no congruency manipulation and no conflict. Thus, a conflict adaptation account is entirely ruled out. This proportion easy effect demonstrates how list-level proportion congruent effects can be driven by non-conflict temporal learning biases.

There is one caveat with the experiment of Schmidt (2013b), however. Proportion easy was manipulated across all items. That is, every letter was presented either most often in high contrast (mostly easy list) or most often in low contrast (mostly hard list). It is conceivable that participants learn biases for specific letter-contrast compounds. For instance, rather than learning the global expectation to respond fast to all easy items in the mostly easy list (list level), they might learn to respond fast to high-contrast *D*, high-contrast *F*, and so on (item-specific). This is a particularly important issue, given that Schmidt used the proportion easy effect as an explanation of list-level proportion congruent effects, which are not biased in this way. If the contrast-based task analogue has only item-specific effects, then this would pose a major problem for the alternative perspective.

An item-specific interpretation of the proportion easy effect might seem reasonable, especially given the fact that item-specific accounts of proportion congruent effects explain most of the variance in those tasks. However, there are also key differences between the two tasks. In the standard proportion congruent task, for instance, the distracting word identity accurately predicts the response to the target (e.g., the word "green" is most often presented with the *white* response). This allows for contingency learning biases. Contrast, however, is *not* predictive of which key to press. Thus, individual-trial contrast cannot provide a viable cue for speeding responses.

On the other hand, frequent letter-contrast compounds may be more familiar to participants. For instance, in the mostly easy list high-contrast *D* is viewed more often than low-contrast *D*, thus leading to a potential advantage for more familiar high-contrast stimuli. The reverse is true in the mostly hard list, where *low-contrast* stimuli are more familiar. However, there is some evidence to suggest against the presence of compound stimulus familiarity effects in simpler RT tasks. For instance, Schmidt, Crump, Cheesman, and Besner (2007; see also, Schmidt & De Houwer, 2012b) show that the learning of contingencies between distracting words and target print colours is not driven by familiarity of frequent word–colour pairs, but instead by word–response contingencies. Nevertheless, this particular contrast paradigm might have different properties than the paradigms used in previous work. For instance, Risko, Blais, Stolz, and Besner (2008) give evidence for familiarity effects in spatial cuing.

Furthermore, even if participants are learning temporal information during the task, it could be that they learn how fast to make *individual* responses. For instance, they could be learning how fast to press the *D* key, how fast to press the *F* key, and so on. This sort of response-specific temporal learning would be interesting, of course. However, it would not be able to explain list-level proportion congruent effects across all responses, for which the transfer items of interest have no item-specific temporal manipulation. In order to address these ambiguities, Experiment 1 adopts a context/transfer methodology more similar to Hutchison (2011). Experiment 2 generalises the findings to a non-contrast manipulation of contingencies.

EXPERIMENT 1

Experiment 1 manipulates list-level proportion easy with *context items*, which do vary in proportion easy, and intermixes these with *transfer items*, which do not vary in proportion easy. For instance, in the mostly easy list two of the letters (e.g., *D* and *F*) are presented most often in high contrast (context items), whereas the other two letters (e.g., *J* and *K*) are presented equally often in high and low contrast (transfer items). Conversely, in the mostly hard list, the context items (*D* and *F*) are presented most often in low contrast, and the transfer items are again presented equally often in high and low contrast. Of course, an effect for context items should certainly be expected (replicating Schmidt, 2013b). The critical question is what happens with transfer items. Do they also display a proportion easy effect despite not having an item-specific manipulation? If temporal learning occurs across the task as a whole, then a proportion easy effect should be observed for both context and transfer items. On the other hand, if the entire effect is driven by item-specific compound stimulus biases, then an effect should only be observed for context items. Of course, it is also conceivable that both a list-level and an item-specific effect will be observed, which would be reflected by a smaller, but significant effect for transfer items. This experiment also manipulates proportion easy within participants in two separate blocks, rather than between participants.

Method

Participants. A total of 105 undergraduate students participated in the experiment in exchange for either €4 or €5.[2]

Apparatus. Stimulus presentation and response timing were controlled with E-Prime 2 (Psychology Software Tools, Pittsburgh, PA). Participants pressed the *D*, *F*, *J* and *K* keys for *D*, *F*, *J* and *K*, respectively.

Materials and design. Stimuli were presented on a light grey background (RGB: 100, 100, 100). Stimuli consisted of the letters *D*, *F*, *J* and *K* presented in uppercase, bold, 18 pt. Courier New font. High-contrast stimuli were presented in a blackish grey (200, 200, 200). Low-contrast stimuli were presented in a light grey (110, 110, 110).[3] In the mostly easy list, two of the letters (either *D* and *F* or *J* and *K*) were presented 90% of the time in high contrast and 10% in low contrast. In the mostly hard list, the same two letters were presented 90% of the time in *low* contrast and 10% in *high* contrast. These were the context items. In both lists, the remaining two letters were presented 50% of the time in both high and low contrast. These were the transfer items. Participants performed both a mostly easy and a mostly hard block. Each block had a total of 200 trials, selected randomly with replacement. The order of the blocks and which two letters were manipulated for contrast proportions were counterbalanced across participants.

Procedure. Each trial began with a white fixation cross for 250 ms, followed by a blank screen for 750 ms, followed by the stimulus for 2,000 ms or until a response was made. Following correct responses, the next trial began immediately. Following incorrect responses or trials where participants failed to respond in 2,000 ms, "XXX" in red (255, 0, 0) was presented for 500 ms before the next trial.

[2] The default payment for participants in the department increased partway through the experiment.

[3] Of course, monitor settings will affect how a given RGB value is displayed. Although a light reader was not available for more precise measurement, monitors were set to fairly standard settings, which made high-contrast stimuli easily perceivable and low-contrast stimuli perceivable but not immediately. Any variance across testing computers did not affect the general direction of effects reported.

Results

Mean correct response latencies and percentage errors were assessed. Trials on which participants failed to respond in 2,000 ms were excluded from the analyses. Initial analyses including the factors of block order and the counterbalancing of letters used as context items revealed some significant, but uninteresting effects (e.g., those having to do with the general speedup in response latencies over time found in all RT experiments). More importantly, no interactions with the key analyses were found. Thus, these two counterbalancing factors were dropped from the analysis and are not discussed further.

Response latencies. The response latency results are presented in Figure 2a. First, a 2 contrast (high vs. low) × 2 proportion easy (mostly easy vs. mostly hard) × 2 item type (context vs. transfer) within-subjects analysis of variance (ANOVA) was conducted on the response latencies. Unsurprisingly, this analysis revealed a significant overall effect of contrast, $F(1, 104) = 82.600$, mean squared error (MSE) = 9023, $p < .001$, $\eta_p^2 = .44$, indicating faster responses to high-contrast stimuli. There were no main effects of proportion easy, $F(1, 104) = .651$, $MSE = 3882$, $p = .422$, $\eta_p^2 < .01$, or item type, $F(1, 104) = .387$, $MSE = 5498$, $p = .535$, $\eta_p^2 < .01$. Item type did not interact with contrast, $F(1, 104) = .276$, $MSE = 1894$, $p = .600$, $\eta_p^2 < .01$, or proportion easy, $F(1, 104) = 1.131$, $MSE = 2077$, $p = .290$, $\eta_p^2 = .01$. Critically, contrast and proportion easy significantly interacted, $F(1, 104) = 9.160$, $MSE = 2313$, $p = .003$, $\eta_p^2 = .08$, replicating the proportion easy effect. Numerically, the proportion easy effect was larger for context relative to transfer items, but this three-way interaction was only marginal, $F(1, 104) = 3.566$, $MSE = 1019$, $p = .062$, $\eta_p^2 = .03$. Most critically, the proportion easy effect was significant for both contexts, $F(1, 104) = 8.763$, $MSE = 2418$, $p = .004$, $\eta_p^2 = .08$, and transfer items, $F(1, 104) = 3.977$, $MSE = 915$, $p = .049$, $\eta_p^2 = .04$.

Percentage error. The percentage error data are presented in Figure 2b. A 2 contrast (high vs. low) × 2 proportion easy (mostly easy vs. mostly hard) × 2 item type (context vs. transfer) within-subjects ANOVA was conducted. This analysis revealed no main effects of contrast, $F(1, 104) = .582$, $MSE = 22.5$, $p = .447$, $\eta_p^2 < .01$, proportion easy, $F(1, 104) = 1.790$, $MSE = 26.3$, $p = .184$, $\eta_p^2 = .02$, or item type, $F(1, 104) = 1.158$, $MSE = 38.3$, $p = .284$, $\eta_p^2 = .01$. There were no significant interactions between item type and contrast, $F(1, 104) = 1.273$, $MSE = 19.7$, $p = .262$, $\eta_p^2 <= .01$, item type and proportion easy, $F(1, 104) = .593$, $MSE = 23.0$, $p = .443$, $\eta_p^2 < .01$, or contrast and proportion easy, $F(1, 104) = .108$, $MSE = 24.3$, $p = .743$, $\eta_p^2 < .01$. The three-way interaction was also not significant, $F(1, 104) = 1.646$, $MSE = 23.2$, $p = .202$, $\eta_p^2 = .02$, though was numerically in the same direction as the response latencies. Overall, errors were infrequent and low in reliability. Most importantly, no evidence for a speed–accuracy trade-off was observed.

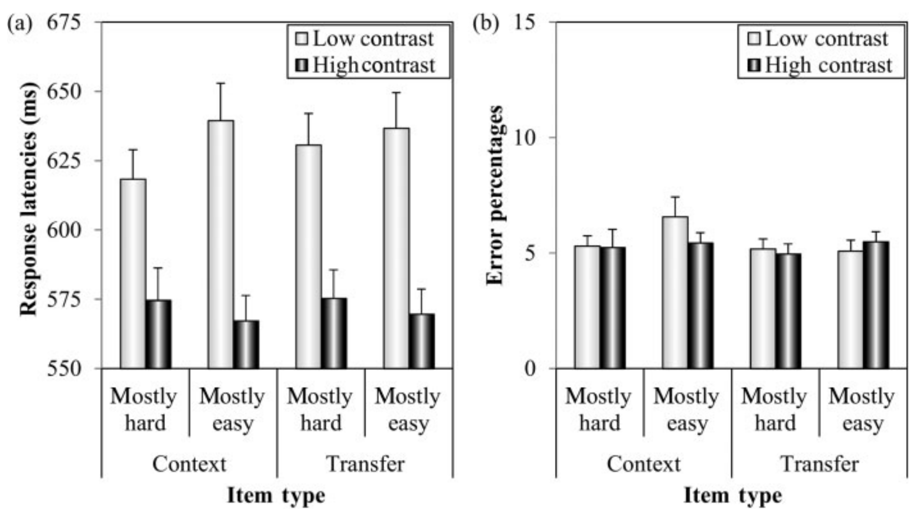

Figure 2. Experiment 1. (a) Response latencies in milliseconds and (b) percentage errors for contrast, proportion easy, and item type, with standard error bars.

Discussion

Experiment 1 served three purposes. First, the experiment replicated the proportion easy effect of Schmidt (2013b). Second and more critically, the results of the experiment serve to alleviate potential concerns with the previous methodology. The original proportion easy effect could have been due to several different things. In addition to list-level temporal learning, it could have been that item-specific temporal learning, compound-stimulus familiarity or response-specific temporal learning drives this key interaction. For the transfer items in the current experiment, however, this was not the case. For these items, there were no item- or response-specific temporal biases, and there were no differences in stimulus frequency/familiarity across the two lists. Indeed, the use of context and transfer items makes the current methodology more similar to Hutchison's (2011) list-level proportion congruent manipulation. Third, the methodology also allowed for a comparison between frequency-biased context items and frequency-unbiased transfer items. Such a comparison makes it possible to assess whether item-specific temporal learning contributes above and beyond the effect of list-level temporal learning. Numerically, there was some hint of this. However, the critical interaction was only marginal and should therefore not be interpreted too strongly. Together, these results strengthen the argument that list-level temporal learning does occur, even for frequency- and temporally unbiased items.

EXPERIMENT 2

Experiment 1 presented evidence that the proportion easy effect with a contrast manipulation is due, at least primarily, to list-level learning. One remaining concern may be that alternative interpretations of the contrast data are still possible. For instance, one might argue that in the mostly hard list participants squint more to better perceive the frequent low contrast targets, and this is what produces a reduced contrast effect. One might also argue that there is a sort of perceptual conflict for low-contrast items, perhaps such that low-contrast letters have a higher tendency of biasing the wrong letter responses. Though alternative interpretations like these are purely speculative, they have some plausibility. To strengthen the claim that proportion easy and proportion congruency effects both may be due to simple temporal learning confounds, Experiment 2 sought to replicate Experiment 1, but with an entirely different manipulation of proportion easy.

Rather than using high- and low-contrast target letters, Experiment 2 used colour targets and neutral word distracters. Each word was presented most often in a certain colour (e.g., "rent" most often in purple), making for *high-contingency items* ($rent_{purple}$) and *low-contingency items* ($rent_{orange}$). Despite a general lack of awareness of the manipulation, participants are known to respond faster and more accurately to high-contingency items (Schmidt et al., 2007; Schmidt & De Houwer, 2012a, 2012b, 2012c, 2012d; Schmidt, De Houwer, & Besner, 2010). Thus, high-contingency trials are fast, and low-contingency or non-contingency trials are slow. For this experiment, *transfer items* had a moderate 70% contingency, and other *context items* had either a strong 90% contingency (mostly easy) or a noncontingent 50% contingency (mostly hard). The key analysis is whether the contingency effect is larger for transfer items in the mostly easy context relative to the mostly hard context. Not only is this manipulation entirely different from the contrast manipulation (while remaining conceptually identical from the temporal learning perspective), but it also bears even more similarity with the work of Hutchison (2011). Similar contingencies were also present in the design of Hutchison. The only notable difference here is the lack of a congruency manipulation. Thus, conflict is again removed, but temporal learning should still be possible.

Unlike the contrast manipulation, it is more likely that block effects will be observed in the current experiment. Contingency learning effects are known to transfer after changes in contingency proportions (Schmidt et al., 2010), so it may be the case that the second block of trials (i.e., where participants switch from mostly easy to mostly hard, or vice versa) may be confounded with biases from the previous block. Thus, one potential result is a clear proportion easy effect for the first block, with less clear results for the second.

Method

Participants. A total of 40 undergraduate students participated in the experiment in exchange for €5. One participant was sick and notably very distracted during the experiment (e.g., checking her phone, looking away from the screen and missing

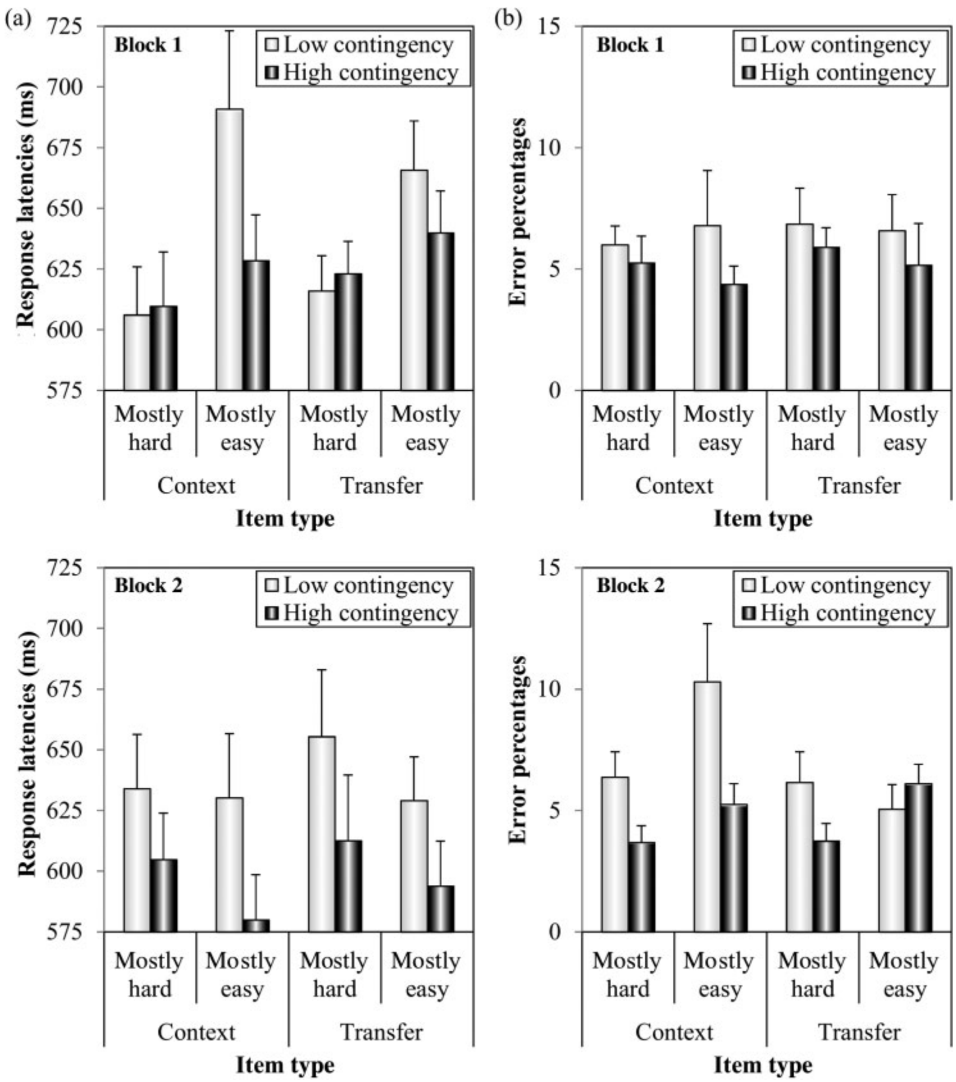

Figure 3. Experiment 2. (a) Response latencies in milliseconds and (b) percentage errors for contingency, proportion easy, item type, and block, with standard error bars.

strings of trials to blow her nose). Prior to looking at the data it was decided to drop this participant. Excluding this participant did affect the significance of the transfer effect observed later.

Apparatus. Stimulus presentation and response timing were again controlled with E-Prime 2 (Psychology Software Tools, Pittsburgh, PA). Participants pressed the *D*, *F*, *J* and *K* keys for *purple*, *orange*, *pink* and *grey*, respectively.

Materials and design. Stimuli were presented on a white background (RGB: 255, 255, 255). Stimuli consisted of the Dutch distracting words *huur* (rent), *kijk* (look), *vind* (find) and *neem* (take), each presented in one of two sets of target colours: *purple* (128, 0, 128) and *orange* (255, 140, 0), or *pink* (255, 0, 255) and *grey* (128, 128, 128), for a total of eight unique stimuli. Two words were presented only in purple and orange, and two others were presented only in pink and grey. One set of colours (e.g., purple and orange) served as context items, and the other set (e.g., pink and grey) served as transfer items. Within the transfer set, one word was presented seven of 10 times (70%) in one colour (e.g., pink) and 3 of 10 times (30%) in the remaining colour. The other word had the reverse proportions. These contingencies remained the same in the mostly easy and mostly hard blocks. Within the context set, the proportions depended on the proportion easy block. In the mostly easy block, one word was presented

9 of 10 times (90%) in one colour and 1 of 10 times (10%) in the remaining colour. The other word had the reverse proportions. In the mostly hard block, both words were presented 5 of 10 times (50%) in both colours. Thus, there is a high preponderance of high-contingency items in the mostly easy block but much less in the mostly hard block. The prediction is for a larger contingency effect in the mostly easy block, even for transfer items. Each of the two blocks had a total of 200 trials, selected randomly with replacement. Words were presented in italic 24 pt. Times New Roman font. Which words were presented with which colours was randomly determined for each participant. Which two colours served as the context items and the order of the two blocks were both counterbalanced.

Procedure. Each trial began with a white screen for 1,000 ms, followed by the stimulus for 2,000 ms or until a response was made. Following correct responses, the next trial began immediately. Following incorrect responses or trials where participants failed to respond in 2,000 ms, "XXX" in red (255, 0, 0) was presented for 500 ms before the next trial.

Results

Again, mean correct response latencies and percentage errors were assessed, and trials on which participants failed to respond in 2,000 ms were excluded from the analyses.

Response latencies. Unlike Experiment 1, initial analyses did reveal meaningful differences when including the factor of block order in the ANOVA. Of particular importance, not only did proportion easy and contingency interact as predicted, $F(1, 37) = 9.790$, $MSE = 1570$, $p = .003$, $\eta^2_p = .21$, but there was also a three-way interaction between proportion easy, contingency, and block order, $F(1, 37) = 4.958$, $MSE = 1570$, $p = .032$, $\eta^2_p = .12$. Thus, the predicted interaction between proportion easy and contingency was observed, with larger effects in the mostly easy list, but this was not independent of block order. The results were therefore analysed separately for each block using ANOVAs with contingency (high vs. low) and item type (context vs. transfer) as within factors and proportion easy (mostly easy vs. mostly hard) as a between factor. The data for both blocks are presented in Figure 3a.

Block 1. The analysis on Block 1 revealed a main effect of contingency, $F(1, 37) = 6.498$, $MSE = 2254$, $p = .015$, $\eta^2_p = .15$, indicating faster responding to high-contingency trials. There were no main effects of item type, $F(1, 37) = .061$, $MSE = 3718$, $p = .807$, $\eta^2_p < .01$, or proportion easy, $F(1, 37) = 2.872$, $MSE = 24568$, $p = .099$, $\eta^2_p = .07$. Critically, the contingency by proportion easy interaction was significant, $F(1, 37) = 10.560$, $MSE = 2254$, $p = .002$, $\eta^2_p = .22$, indicating a larger contingency effect in the mostly easy list. Interestingly, item type did not interact with contingency, $F(1, 37) = 1.976$, $MSE = 1976$, $p = .168$, $\eta^2_p = .05$, proportion easy, $F(1, 37) = .898$, $MSE = 3718$, $p = .349$, $\eta^2_p = .02$, or with contingency and proportion easy, $F(1, 37) = 1.343$, $MSE = 1976$, $p = .254$, $\eta^2_p = .04$. The contingency effect was significantly larger in the mostly easy list for both context items, $t(37) = 2.523$, $SE_{\text{diff}} = 26$, $p = .016$, $\eta^2 = .15$, and transfer items, $t(37) = 2.418$, $SE_{\text{diff}} = 14$, $p = .021$, $\eta^2 = .14$.

Block 2. In sharp contrast to Block 1, the only significant result in the ANOVA for Block 2 was the main effect of contingency, $F(1, 37) = 32.747$, $MSE = 1845$, $p < .001$, $\eta^2_p = .47$. All other comparisons were not reliable, $F\text{s} \leq 1.083$, $p\text{s} \geq .305$. Of particular importance, the contingency by proportion easy interaction was non-significant, $F(1, 37) = .240$, $MSE = 1845$, $p = .672$, $\eta^2_p < .01$.

Percentage error. The error data are presented in Figure 2b. Generally speaking, the errors were much less sensitive than RTs. The ANOVA with contingency (high vs. low), item type (context vs. transfer), and proportion easy (mostly easy vs. mostly hard) as within factors and block order (Block 1 vs. Block 2) as a between factor revealed only a main effect of contingency, $F(1, 37) = 9.148$, $MSE = 28.6$, $p = .005$, $\eta^2_p = .20$, indicating less errors to high-contingency trials. Of particular importance, the contingency by proportion easy interaction was not significant, $F(1, 37) = .114$, $MSE = 11.4$, $p = .737$, $\eta^2_p < .01$, nor was the three-way interaction between contingency, proportion easy, and block order, $F(1, 37) = 1.352$, $MSE = 11.4$, $p = .252$, $\eta^2_p = .04$. Given these non-significant results, the remaining contrasts are largely irrelevant.

Discussion

Experiment 2 served to extend the findings of the contrast experiments to a completely novel manipulation of response speed. Much like the previous experiment, the manipulation of contingencies served to produce a proportion easy effect for both context and transfer items. Interestingly, it was again observed that there was no effect of item type. Numerically, however, there was again a hint of a larger effect for context items, but this was far from significant. It is again possible that the study merely lacked sufficient power, especially given the smaller sample size and the need to switch to a between-group comparison (i.e., due to the block effects). That said, these results provide evidence that at least the majority of the temporal learning effect occurs at the list level. Experiment 2 also provided evidence for transfer from one block to the next, unlike Experiment 1. This is probably because transfer of contingency information from the first block (partially) biases the effect in the reverse direction during the second block, consistent with past results (Schmidt et al., 2010). Thus, with the contingency preparation, between group rather than blocked testing may be needed.

REANALYSIS 1: PROPORTION EASY DELTA PLOT

Another question that may help to distinguish between temporal learning and conflict adaptation is a distributional analysis. One method for approaching this issue is with delta plots (De Jong, Liang, & Lauber, 1994). Delta plots use Vincentized (binned) data to investigate the development of an effect over time. Temporal learning biases should have the effect of speeding many RTs, leading to speeded easy trials in the mostly easy condition relative to the mostly hard condition and speeded hard trials in the mostly hard condition relative to the mostly easy condition. These two effects will not necessarily be constant over time, however. For instance, one would expect an effect on the fastest responses in each condition, as well as in the intermediate responses. However, one part of the distribution that should almost never be affected is the slowest responses. This is because changes to the response deadline should almost always return to normal later in the trial. That is, if the temporal expectation is missed, no effect of mostly hard vs. mostly easy should be observed any longer. The temporal learning account will not necessarily predict a linear negative slope, that is, parametrically decreasing the effects from the fastest to the slowest responses. Instead, the prediction is merely for very weak effects in the slowest of responses.

This is in stark contrast to what most models of performance would suggest. For instance, the conflict monitoring account suggests that there should be changes in the amount of attention paid to the distracter in the mostly congruent and mostly incongruent conditions. This account, of course, cannot predict much at all in the two experiments reported in the current manuscript, given the lack of a conflict manipulation. That said, if the account predicts anything, then it should be for increasing effects with longer lags. That is, the longest RTs should be those that are the *most* affected, as attentional differences can only have an accumulative effect. Indeed, with paradigms like the Stroop task using simultaneous presentation of targets and distracters delta plots are typically positive (Pratte, Rouder, Morey, & Feng, 2010). That is, the effect in question will increase with longer bins, being the largest in the slowest bins and the smallest in the fastest bins.

Thus, Reanalysis 1 introduced delta plots to the data of Experiment 1 to test for these two possible patterns. The data of Experiment 1 were selected over those of Experiment 2 for a number of reasons. First, Experiment 1 had a much larger sample size. Second, the contingency manipulation in Experiment 2 meant for very few observations in the low-contingency condition, even for the transfer items, making it difficult to split up the distribution into bins. Furthermore, the block effects found in Experiment 2 meant that only the Block 1 RTs would have been useful, further reducing the number observations analyzable for delta plots.

Method

To conduct the delta plot analyses, the correct RT data for the frequency-unbiased transfer items were split into separate distributions for each of the four conditions making up the contrast by proportion easy interaction for each participant. Each of these distributions was then divided into 10 equally sized bins, starting from the first 10% fastest trials, then the next 10%, and so on. After averaging across participants, a proportion easy effect was calculated for each bin. Specifically, the contrast effect (low and high contrast) for mostly easy items was subtracted from the contrast effect for mostly hard items. The resulting mean

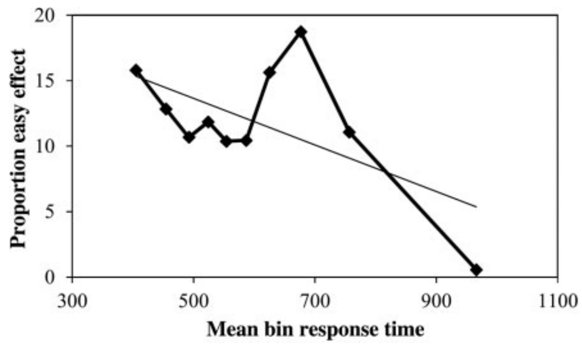

Figure 4. Experiment 1 delta plot of the proportion easy effect, with trend line.

difference scores for each bin were then plotted against the mean RT of the four conditions for that bin.

Results

As can be seen from the delta plot in Figure 4, the proportion easy effect was the smallest in the slowest RT bin, consistent with predictions from the temporal learning view. Indeed, there was a clear null effect of proportion easy in the slowest RTs (Figure 4).

Discussion

The delta plot analyses in Reanalysis 1 confirmed the predictions of the temporal learning view. Specifically, the proportion easy effect was located primarily in the fastest and intermediate responses. The slowest RT bin, in contrast, showed no effect. This is consistent with the notion that the slowest responses miss out on any potential benefits from a temporarily reduced response threshold.

REANALYSIS 2: PROPORTION CONGRUENCY DELTA PLOT

Reanalysis 1 provided further evidence for the temporal learning account of the Experiment 1 data. To bolster the claim that the same learning process might be playing a role in the proportion congruent task, the same analysis was conducted on the proportion congruency data of Hutchison (2011).

Method

Analysis 2 was identical in all respects to Analysis 1, save that proportion congruency and congruency were coded in place of proportion easy and contrast. The correct RT data for the frequency-unbiased transfer items were again split into separate distributions for each of the four conditions making up the congruency by proportion congruency interaction for each participant. Each of these distributions was then divided into 10 equally sized bins, starting from the first 10% fastest trials, then the next 10%, and so on. After averaging across participants, a proportion congruency effect was calculated for each bin. Specifically, the congruency effect (incongruent–congruent) for mostly congruent items was subtracted from the congruency effect for mostly incongruent items. The resulting mean difference scores for each bin were then plotted against the mean RT of the four conditions for that bin.

Results

As can be seen from the delta plot in Figure 5, the proportion congruency effect was the smallest in the slowest RT bin, again consistent with predictions from the temporal learning view. The negative slope on the trend line is again driven by the roughly null proportion congruent effect in the slowest bin (Figure 5).

Discussion

The delta plot analyses in Reanalysis 2 confirmed a similar pattern in proportion congruency data as that observed in Reanalysis 1 with contrast. That is, the proportion congruency effect was located

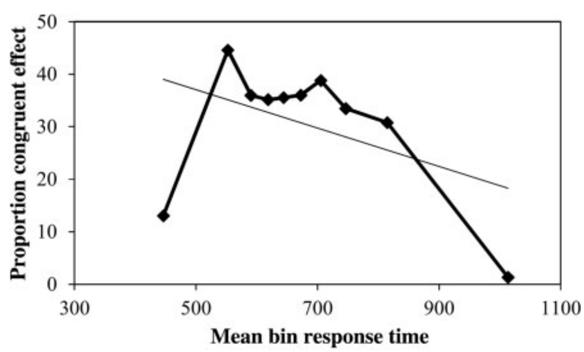

Figure 5. Delta plot of the list-level proportion congruency effect from Hutchison (2011), with trend line.

primarily in the fastest and intermediate responses and obliterated in the slowest RT bin. This is again consistent with the notion that the slowest responses missed out on any potential benefits from a temporarily reduced response threshold.

GENERAL DISCUSSION

In the two experiments presented here it was shown that task-level manipulations of response speed can produce interactions mimicking list-level proportion congruent effects. Despite the lack of conflict in the contrast and contingency paradigms used, "proportion easy" effects were observed for both manipulated context items and non-manipulated transfer items. These results therefore add further credence to the notion that temporal learning contributes to the proportion congruent effect, and that conflict adaptation may not need to be additionally assumed.

As a side question, the experiments also aimed to assess whether item-specific temporal learning was observable. Though there were some subtle hints of this, especially in Experiment 1, no statistically significant evidence for item-specific temporal learning was achieved. Future work could be helpful in assessing this possibility further. Such work could also attempt to distinguish between item-specific temporal learning, response-specific temporal learning and stimulus frequency biases, which were all confounded in the current experimental setups. This could potentially be achieved with a dissociation procedure such as that which has been used in the contingency learning literature (e.g., Schmidt & De Houwer, 2012b; Schmidt et al., 2007).

The present work also presented delta plot analyses of the proportion easy effect with contrast and the list-level proportion congruent effect from Hutchison (2011). In both cases, an elimination of the effect was observed in the slowest of responses. This seems consistent with the temporal learning view. Temporal expectancies will be responsible for speeding a number of the fastest and more immediate responses but are unlikely to affect exceptionally slow responses. Most other accounts, such as the conflict adaptation account, should not predict this pattern. Were either the list-level proportion congruent or proportion easy effects driven by increases in attention to the distracter in the mostly congruent/easy condition, the effect of such attentional changes should only increase with time. Thus, an especially large effect should have been expected in the slowest of responses.

For the proportion congruency literature, there remains the difficult issue of attempting to dissociate between list-level conflict adaptation and list-level temporal learning. This is an even harder problem to resolve than the debate over contingency vs. item-specific conflict adaptation (e.g., Schmidt, 2013c; Schmidt & Besner, 2008). The issue is that temporal biases are almost inherently confounded with congruency in proportion congruent experiments. Incongruent trials are, by their very nature, slower than congruent trials. Indeed, results such as those in the current paper present the case that temporal learning confounds are a concern when interpreting list-level proportion congruent experiments, but do not allow us to definitively conclude whether or not temporal learning is the whole story. It is currently unclear how to resolve this dilemma, and it is hoped that future work will provide a solution. The distributional analyses do present some case that the temporal account might be a better fit, though further evidence would be desirable. At present, however, temporal learning biases are an important consideration to keep in mind when interpreting list-level effects. With no other apparent confounds, list-level proportion congruent effects might otherwise seem to argue strongly for list-level conflict adaptation.

The current results seem to suggest that the majority of the temporal learning effect occurs at the list level, rather than the item level. A different question is what role context might play in temporal learning. If there are two different contexts within a procedure, such as two different display locations or two different text fonts, and each context has a different level of proportion easy, then will participants learn a different temporal expectancy for each context? When *proportion congruency* is manipulated across different contexts in this way, a context-level proportion congruency effect is observed (e.g., Bugg et al., 2008; Crump, Gong, & Milliken, 2006). If these context-level effects are (in whole or in part) driven by temporal learning, then we might expect similar results with another (e.g., contrast) manipulation. Crump and Milliken (2009) further showed context-level transfer effects with proportion congruency. If the temporal learning transfer effects observed in the current report can also be context-specific, then this would provide additional support for the non-conflict interpretation of proportion congruency effects (whether list- or context-based) and provide additional insights into the basic processes involved in temporal learning. Further research on such questions is therefore definitely welcome.

Another interesting question is how item-specific and list-level effects interact. For instance, Hutchison (2011) showed that the item-specific proportion congruency effect within transfer items was larger in the list with mostly congruent context items, relative to mostly incongruent context items. Whether a simple learning account could explain this result is not immediately apparent. The results of Experiment 2, however, might provide one hint: the contingency effect for transfer items was larger in the mostly easy list, relative to the mostly hard list. Although one can only speculate whether it accounts for the findings of Hutchison, it could be that temporal and contingency learning interact with each other. Future research will be needed to assess this possibility.

As a further caveat, it should be noted that the proportion congruent/easy interaction is generally of the greatest interest, but the precise pattern of data is often inconsistent in this work. For instance, the proportion easy interaction of Experiment 2 is seemingly driven more by the low-contingency items, whereas the results in Experiment 1 seem to be more symmetrical. These are only visual impressions, given the lack of main effects for proportion easy in both experiments. However, similar inconsistencies are also observed in proportion congruency experiments (e.g., Cheesman & Merikle, 1986), including a difference between the mostly congruent and mostly incongruent items in Hutchison (2011). Why this occurs is not apparent from either the conflict adaptation or temporal learning perspectives. One possibility is that another process results in an overall speeding or slowing within one of the two proportion congruency/easy lists (e.g., due to differences in response caution; Van Maanen et al., 2011). Further investigation of these issues is thus warranted.

Last, alternative interpretations might be forwarded for both Experiments 1 and 2. As already mentioned, one might argue that participants may have squinted more in the mostly hard condition of Experiment 1 due to the higher preponderance of low-contrast stimuli. This explanation obviously does not work for Experiment 2, where stimulus luminance was not varied, but one might propose yet another account for Experiment 2. For instance, perhaps the overall number of high-contingency trials in the mostly easy condition leads to a stronger reliance on contingency information, even for the unbiased transfer items. This would certainly be interesting if true but is quite speculative. It is also not parsimonious to proffer one account for the Stroop paradigm (e.g., conflict monitoring), another for the contrast experiment (e.g., squinting) and yet a third for the contingency experiment (e.g., list-level adjustments in contingency reliance). Of course, the simplest account is not always the correct one, but Occam's razor should favour the account that explains all three interactions with one mechanism. For this reason, the temporal learning account currently fairs well.

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