



Learning, awareness, and instruction: Subjective contingency awareness does matter in the colour-word contingency learning paradigm

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ABSTRACT

In three experiments, each of a set colour-unrelated distracting words was presented most often in a particular target print colour (e.g., “month” most often in red). In Experiment 1, half of the participants were told the word-colour contingencies in advance (instructed) and half were not (control). The instructed group showed a larger learning effect. This instruction effect was fully explained by increases in subjective awareness with instruction. In Experiment 2, contingency instructions were again given, but no contingencies were actually present. Although many participants claimed to be aware of these (non-existent) contingencies, they did not produce an instructed contingency effect. In Experiment 3, half of the participants were given contingency instructions that did not correspond to the correct contingencies. Participants with these false instructions learned the actual contingencies worse than controls. Collectively, our results suggest that conscious contingency knowledge might play a moderating role in the strength of implicit learning.

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1. Introduction

For many years now, learning researchers have debated about whether the impact of stimulus pairings on behaviour depends on awareness of those contingencies between stimuli (e.g., Lovibond & Shanks, 2002; see Schmidt, 2012). Most often, the relation between both is examined by assessing the impact of stimulus pairings on both performance and awareness measures. Awareness can be assessed subjectively by asking participants to verbally report whether they noticed the contingencies or objectively by presenting forced-choice questions about the nature of the contingencies (see Cheesman & Merikle, 1986, for more on this distinction; see also Dienes, Altmann, Kwan, & Goode, 1995). Regardless of the type of awareness measure, the available evidence about the relation between learning and awareness is mixed. On the one hand, results from several paradigms reveal very sizeable effects of contingency awareness. For instance, in a meta-analysis reported by Hofmann, De Houwer, Perugini, Baeyens, and Crombez (2010) contingency awareness accounted for 37% of the variance in evaluative conditioning, that is, the impact of stimulus pairings on the liking of those stimuli. Indeed, there is still discussion about whether evaluative conditioning without contingency awareness is even possible (Baeyens, Eelen, & Van den Bergh, 1990; Pleyers, Corneille, Luminet, & Yzerbyt, 2007; Schmidt & De Houwer, 2012b; Stahl & Unkelbach, 2009). Similar to these results, research on autonomic conditioning (i.e., the impact of stimulus pairings on autonomic reactions to those stimuli) demonstrates a large role for contingency awareness. Indeed, contingency awareness is generally considered to be a necessary precondition for autonomic conditioning (Dawson & Furedy, 1976; but see Schultz & Helmstetter, 2010).

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On the other hand, learning in several other contingency learning paradigms seems to often occur without awareness. One example of this is the colour-word contingency learning paradigm of Schmidt and colleagues (Schmidt & Besner, 2008; Schmidt, Crump, Cheesman, & Besner, 2007; Schmidt & De Houwer, 2012a, 2012b, 2012c; Schmidt, De Houwer, & Besner, 2010). In this colour identification paradigm, each of a set of neutral words is presented most often in a certain print colour (e.g., “month” in red, “plate” in green, etc.). It is typically found that participants respond faster and more accurately to *high contingency* trials, where the word is presented in its most frequent colour (e.g., “month” in red or “plate” in green), relative to *low contingency* trials, where the word is presented in a less frequent colour (e.g., “month” in green or “plate” in red). This effect is extremely reliable and appears almost instantly (Schmidt et al., 2010).

According to Schmidt et al. (2010), learning in the colour-word contingency learning paradigm occurs as a simple result of episodic memory retrieval biases. Specifically, they suggest that on each trial participants encode an episode containing a record of the distracting word, the target colour, and the response that was made (see Logan, 1988). On subsequent trials, processing of the distracting word will lead participants to retrieve some of the episodes in which that word was presented. As most of the episodes associated with a given word will have the same (high contingency) response, the participant will be biased toward that high contingency response. For instance, if “month” is presented most often in red, then most “month” episodes will have a *red* response encoded. Presentation of “month” will therefore bias a participant to make a *red* response.

Although awareness of the stimuli is likely needed to encode each episodic memory, the learning that occurs in the task is simply an episodic retrieval bias. Participants do not necessarily need to be aware of the contingencies in order for this to occur. Indeed, participants of previous colour-word contingency learning experiments were not informed in advance about the contingencies in the task and post-experiment awareness tests suggest that most participants did not consciously detect them (e.g., Schmidt et al., 2007). Thus, the better performance on high relative to low contingency trials seems to be a case of implicit learning. Similar reports of learning without awareness have been found in a wide array of performance (i.e., response time) paradigms, such as the Eriksen flanker task (Carlson & Flowers, 1996; Miller, 1987), serial response time task (Destrebecqz & Cleeremans, 2001; Jiménez & Méndez, 1999; Mayr, 1996; Nissen & Bullemer, 1987; Song, Howard, & Howard, 2007; Willingham, Nissen, & Bullemer, 1989), and hidden covariation detection tasks (Lewicki, 1985, 1986; Lewicki, Hill, & Czyzewska, 1992), along with other paradigms such as the Hebb digits task (McKelvie, 1987). Some results even suggest that paradigms such as the colour-word contingency paradigm are simply immune to conscious influences. For instance, Schmidt et al. (2007) compared participants at varying levels of contingency awareness and found that the size of the contingency effect was not dependent on the amount of contingency awareness. Specifically, participants were divided up into those who claimed awareness (subjectively aware), those who guessed well which words went with which colours (objectively aware), and those who guessed at or below chance (objectively unaware). All three groups showed a similarly-sized learning effect. Carlson and Flowers (1996, Experiment 1) similarly reported that contingency awareness did not increase learning in the Eriksen flanker task when flankers were presented simultaneously with targets. Likewise, Miller (1987, Experiment 5) found that better guessing of the contingencies between flanking and target letters was not associated with an increased contingency effect.

One could argue that the limited role of contingency awareness in performance tasks such as the colour-word contingency paradigm is related to the concurrent presentation of the related distracters (e.g., a neutral word) and targets (e.g., a print colour). With concurrently presented target and distracting stimuli, there is simply too little time to use contingency knowledge consciously. If, for instance, the participant can identify the colour in 550 ms, then the word would have to be consciously identified and used to predict a response even faster than that in order to speed responding. It seems implausible that this could be done so quickly in an intentional manner. In other words, even if a participant does become aware of the contingencies, there is not enough time to consciously anticipate the response associated with a given distracter word. Thus, contingency knowledge, even if obtained, is effectively useless. If true, this would mean that the colour-word contingency learning paradigm is exactly the type of paradigm mostly likely to be immune to conscious contingency knowledge. In line with this idea, paradigms in which the distracter is presented in advance of the target do often show a positive effect of contingency knowledge, for instance, in a flanker task where flankers were presented in advance of the target (Carlson & Flowers, 1996, Experiment 3) and in sequence learning (e.g., Mayr, 1996).

On the other hand, concluding that conscious contingency knowledge cannot aid learning in tasks where the target and contingent distracter are presented simultaneously requires accepting the null results of only a few experiments. When considering subjective measures of awareness, there are at least two reasons why some previous studies may have failed to reveal a relation between contingency awareness and learning. First, there are reasons to believe that many participants who report being contingency aware are not actually aware of the contingencies. For instance, Bar-Anan, De Houwer, and Nosek (2010) showed that participants will often claim to subjective awareness when contingencies are not even present in the task. Similar problems arose in studies by Schmidt et al. (2007): when probed for what contingencies “aware” participants noticed, most gave answers unrelated to contingencies (e.g., “I think I saw yellow a lot”). In all likelihood, these participants were not actually aware of the contingencies and misunderstood the question that probed for contingency awareness. Second, a positive relation between subjective awareness and learning might also have gone unnoticed in previous experiments because of floor effects in awareness. When virtually all participants are contingency unaware, it is impossible to detect a positive impact of contingency awareness on learning.

Moreover, even if the encoding and retrieval of episodes occurs in a largely implicit way, explicit knowledge of contingencies could alter *how* trial information is encoded. For instance, knowing the contingencies could lead participants to encode high contingency trials more strongly (i.e., because they are consistent with the contingencies that they have explicit in

mind) and low contingency trials more weakly (i.e., because they are inconsistent). This preferential encoding of high contingency trials would thus lead to even stronger retrieval of the high contingency response.

Furthermore, there is some evidence that suggests that contingency awareness can be beneficial in contingency learning, so long as the contingencies to be learned are very simple. For instance, Broadbent, FitzGerald, and Broadbent (1986) used the dynamic systems task in which participants need to set the imaginary fee for car parks and the interval between busses to obtain both a certain optimal use of the car parks (i.e., not too much and not too little) and a certain optimal number of free spaces on the busses. Decreasing the frequency of busses both decreases bus use and increases parking space use, and increasing parking fees both increases bus use and decreases parking use. Thus, achieving both goals (parking space and bus use) requires a complex interaction between the two variables that participants can manipulate (parking fees and bus regularity). When participants are given instructions about how to perform the task, the instructions are generally unhelpful. The contingencies are too complex for awareness to help. However, if participants are given instructions and the opportunity to practice how parking fees and bus regularity affect the outcomes separately (e.g., by first practicing the effect of parking fees on the outcomes and then practicing the effect of bus regularity on the outcomes), learning in the combined task is greatly improved. That is, participants are able to consciously learn much simpler contingencies (i.e., learning one simple contingency relation at a time rather than an interaction between two) in order to piece together the more complex problem. Thus, contingency awareness from instructions seems to aid learning if the contingencies to be learned are more simple. Given how simple the contingencies are in the colour-word contingency paradigm, it might be possible after all to observe a benefit of contingency awareness for implicit learning. We therefore decided to re-examine the relation between subjective contingency awareness and learning in the colour-word contingency learning task.

2. Experiment 1

We chose to use the colour-word contingency learning task because previous results suggest that learning in this task is independent of awareness. Furthermore, the task is interesting because the associated stimuli (i.e., the word and the colour) are presented simultaneously and very shortly before the response. If we could demonstrate that learning in this paradigm is influenced by subjective contingency awareness, it would show that contingency awareness can matter even in situations where there is very little time to use conscious contingency knowledge in order to speed up performance. To avoid incorrect reporting of contingency awareness, we clarified the question probing for contingency awareness by clearly explaining the type of contingency relationships we were asking about (see Methods). To avoid floor effects, we also took measures to increase the number of participants who became aware of the contingencies. More specifically, we increased the strength of the contingencies (i.e., 80% rather than 50% trials in which a word was presented in its assigned colour). Moreover, we warned half of the participants before the start of the task that words would be printed more often in a specific colour and gave them the specific pairings. By highlighting the contingencies in this manner, we hoped to increase the number of contingency-aware participants. To avoid a situation in which all participants are contingency aware, half of the participants were not informed about the colour-word contingencies. Finally, in addition to registering subjective awareness, we also assessed objective contingency awareness following the main learning task.

2.1. Method

2.1.1. Participants

Sixty-two Ghent University undergraduates participated in Experiment 1 in exchange for €4. As was the case in all other experiments, all participants were native Dutch speakers.

2.1.2. Apparatus

Stimulus and response timing were controlled by E-Prime software (Psychology Software Tools., 2002). Using an AZERTY keyboard, participants pressed the “J” key for red, the “K” key for yellow, and the “L” key for green.

2.1.3. Materials and design

Participants sat approximately 60 cm from the screen. In this experiment, three neutral five-letter Dutch words (onder [under], maand [month], plaat [plate]) were presented in three different print colours (red, yellow, green). Each word was presented most often in one colour. For instance, “onder” might have been presented 80% of the time in red, “maand” 80% of the time in yellow, and “plaat” 80% of the time in green. Which word went with which colour was randomly determined for each participant. Words were presented equally often in the other two colours. Words were presented in bold, 18 pt. Courier New font on a black background. The RGB values for the display colours were 255,0,0 (red), 255,255,0 (yellow), and 0,255,0 (green). Participants saw a total of 300 trials selected at random with replacement (i.e., after a trial was presented it was not removed from the list of possible future trials).

2.1.4. Procedure

Participants were first given the instruction that they would be responding to the print colour of words. Participants in the instructed group received the following second instruction screen telling them of the word-colour contingencies involved in the task (English translation):

Note: Each word in the experiment is presented most often in a certain colour. Specifically, the word “month” is presented most often in red, the word “under” is presented most often in yellow, and the word “plate” is presented most often in green. Remember these color-word relationships as you perform the task.

Note that this is a sample word-colour mapping. Which word was presented with which colour was randomly determined for each participant. Participants in the control group were not presented with this second instruction screen. On each trial in the task, participants first saw a white fixation “+” for 150 ms, followed by a blank screen for 150 ms, followed by the coloured word for 2000 ms or until a response was made. After a response was made, the next trial started if the participant’s response was correct. If the participant responded incorrectly or failed to respond in 2000 ms, “XXX” in white was presented for 500 ms before the next trial. Following the main procedure, participants were presented with the following subjective awareness question telling them that each word was presented most often in a certain colour and asking them if they noticed these relationships (English translation):

In this experiment, each word was presented most often in a certain colour. Specifically, one word was presented most often in red, one word was presented most often in yellow, and one word was presented most often in green. Did you notice these relationships?

Note that the second of the three sentences was added to increase clarity. Following this, participants were probed for objective awareness with three forced choice questions. On each of these questions, the participant was presented with one of the three display words in white and was asked to guess which colour it was presented in most often (i.e., three-alternative forced choice). Thus, objective awareness was a scale variable on which 0%, 33%, 67%, and 100% were the only possible values for a given participant.

2.2. Results

In this and the following experiments mean correct response latencies and percentage error data were analysed. Trials on which participants failed to respond (less than 1% of the data) were removed from analyses.

2.2.1. Instruction

The response latency and error data for the two instruction groups are presented in Fig. 1. Overall, participants responded significantly faster to high (533 ms) relative to low contingency trials (572 ms), $t(61) = 7.621$, $SE_{diff} = 5$, $p < .001$, $\eta_p^2 = .49$, and also with less errors (4.3% and 9.4%, respectively), $t(61) = 6.528$, $SE_{diff} = .8$, $p < .001$, $\eta_p^2 = .41$. Most importantly, the size of the contingency effect (low – high contingency) was significantly larger in the instructed group in errors, $t(61) = 2.450$, $SE_{diff} = 1.5$, $p = .017$, $\eta_p^2 = .09$, and marginal in response latencies, $t(61) = 1.793$, $SE_{diff} = 10$, $p = .078$, $\eta_p^2 = .05$. Planned comparisons revealed that the contingency effect was significant for instructed participants in response latencies (high: 525 ms; low: 573 ms), $t(30) = 6.327$, $SE_{diff} = 8$, $p < .001$, $\eta_p^2 = .57$, and errors (high: 4.6%; low: 11.5%), $t(30) = 5.800$, $SE_{diff} = 1.2$, $p < .001$, $\eta_p^2 = .53$. The contingency effect was also significant for control participants in response latencies (high: 541 ms; low: 571 ms), $t(30) = 4.546$, $SE_{diff} = 7$, $p < .001$, $\eta_p^2 = .41$, and errors (high: 4.0%; low: 7.2%), $t(30) = 3.590$, $SE_{diff} = .9$, $p = .001$, $\eta_p^2 = .30$.

2.2.2. Subjective awareness

A total of 84% (26 of 31) of participants in the instructed group and 52% (16 of 31) of the participants in the control group said that they were aware of the presence of colour-word contingencies. The difference in rates of subjective awareness in the two groups was statistically significant, $t(60) = 2.847$, $SE_{diff} = 11$, $p = .006$, $\eta_p^2 = .12$. Technically, 100% of participants should have been subjectively aware in the instructed group, perhaps indicating that the five that said they were not aware did not read the instructions (particularly given the fact that the subjective awareness question was almost verbatim iden-

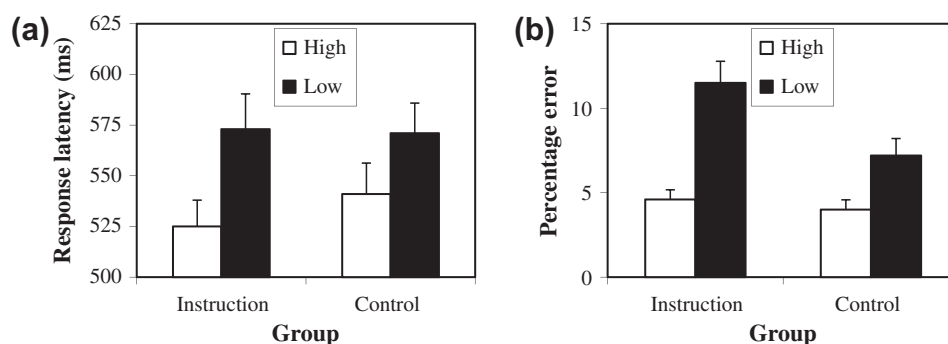


Fig. 1. Experiment 1 (a) response latencies and (b) error percentages as a function of contingency and instruction group. The bars represent standard errors.

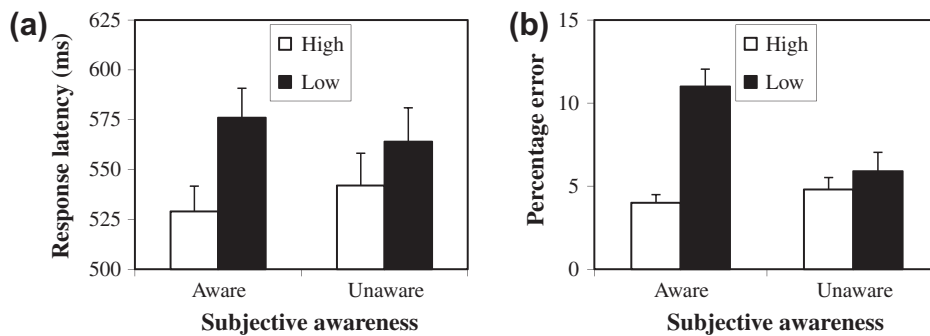


Fig. 2. Experiment 1 (a) response latencies and (b) error percentages as a function of contingency and subjective awareness. The bars represent standard errors.

tical to the contingency instruction; see Methods). The response latency and percentage error data are presented in Fig. 2. Importantly, subjective awareness *did* matter in this experiment, as subjectively aware participants showed a larger contingency effect (low minus high contingency trials) than subjectively unaware participants in response times, $t(60) = 2.336$, $SE_{diff} = 11$, $p = .023$, $\eta_p^2 = .08$, and in errors, $t(60) = 3.928$, $SE_{diff} = 1.5$, $p < .001$, $\eta_p^2 = .20$. The data of subjectively aware and unaware participants were then analysed separately. Subjectively-aware participants produced a significant contingency effect in response times, $t(41) = 7.305$, $SE_{diff} = 6$, $p < .001$, $\eta_p^2 = .57$, and errors, $t(41) = 7.490$, $SE_{diff} = .9$, $p < .001$, $\eta_p^2 = .58$. Importantly, subjectively-unaware participants also produced a significant contingency effect in response times, $t(19) = 3.101$, $SE_{diff} = 7$, $p = .006$, $\eta_p^2 = .34$, though not in errors, $t(19) = 1.181$, $SE_{diff} = .9$, $p = .252$, $\eta_p^2 = .07$.

2.2.3. Mediation

Because the instruction manipulation increases subjective awareness and subjective awareness is predictive of the size of the contingency effect it could be the case that the effect of instructions on the contingency effect is indirectly due the associated increases in contingency awareness (i.e., mediation). To test this, we first combined response latency and error effects (low contingency – high contingency) by calculating the principle component of the two and ran a series of regressions. Note that this principle component is simply a measure of the contingency effect that combines what the response latency and error effects have in common.¹ Instruction group significantly correlated with subjective awareness, $\beta = .345$, $p = .006$, and with the contingency effect, $\beta = .309$, $p = .014$. However, when awareness and group were added into a regression together as predictors and the contingency effect as the dependent variable, only awareness correlated significantly with the contingency effect, $\beta = .373$, $r_{Y(1,2)} = .368$, $p = .004$. Group and the contingency effect did not correlate significantly in this analysis, $\beta = .181$, $r_{Y(1,2)} = .188$, $p = .164$. A Sobel test (Baron & Kenny, 1986) confirmed significant mediation, $Z = 2.024$, $SE = .126$, $p = .043$. Thus, the effect of instruction group on the contingency effect is mediated by contingency awareness. Furthermore, the non-significant semipartial correlation for group suggests that group is fully (or at least primarily) mediated by contingency awareness.

2.2.4. Objective awareness

Participants in the instructed group also scored significantly higher on the objective awareness task (98%) than participants in the control group (86%), $t(60) = 2.142$, $SE_{diff} = 6$, $p = .036$, $\eta_p^2 = .07$. Guessing in the objective awareness test was well above chance (i.e., 33%) in both the instructed, $t(30) = 29.846$, $SE_{diff} = 2$, $p < .001$, $\eta_p^2 = .97$, and control participants, $t(30) = 10.355$, $SE_{diff} = 5$, $p < .001$, $\eta_p^2 = .78$. Unlike subjective awareness, objective awareness was not related to the size of the contingency effect in response times, $r(60) = -.004$, $p = .978$, or in errors, $r(60) = .121$, $p = .349$. Interestingly, subjective and objective awareness did not correlate, $r(60) = .008$, $p = .949$.

2.3. Discussion

Experiment 1 demonstrated that contingency learning effects in the colour-word contingency learning paradigm *do* benefit from subjective contingency awareness. Subjectively aware participants showed larger contingency effects in both response times and errors relative to subjectively unaware participants. Objective awareness, in contrast, did not seem to matter, as objective awareness was uncorrelated with the size of the learning effect. Regarding this latter result, however, it is worth noting that performance in the objective awareness test was near ceiling, which may be concealing any effect that might exist. We will discuss this in further detail in the General Discussion.

¹ The error and response latency data were combined in this way in order to simplify the reporting of the data. Separate analyses on errors and response latencies parallel the results with a single principle component.

3. Experiment 2

The results of Experiment 1 leave open the question of *how* subjective contingency knowledge benefits performance in learning tasks such as the colour-word contingency learning paradigm. One possibility is that contingency knowledge has a *direct* effect on learning. That is, the explicit representation of contingency knowledge in memory helps to directly activate the expected response. If this were the case, then explicit knowledge of the contingency relations should be sufficient to produce a contingency learning effect, even if implicit learning is impossible. This seems a plausible outcome. In autonomic conditioning research, it has been shown that merely instructing participants that a green light indicates an increased likelihood of a shock (even though it does not) results in participants having a galvanic skin response to the light (i.e., fear conditioning; Cook & Harris, 1937). However, the autonomic conditioning paradigm is quite different than our own, so it is not clear whether similar results will be obtained. To this end, participants in Experiment 2 received contingency instructions identical to those presented to participants in the instructed group of Experiment 1, but no contingencies were actually present in the task. That is, although participants were told which words would be (supposedly) presented most often in which colours, in reality all words were presented equally often in the three colours.

3.1. Method

3.1.1. Participants

Fifty-three Ghent University undergraduates participated in Experiment 2 in exchange for €4.

3.1.2. Apparatus

The apparatus for Experiment 2 was identical to that of Experiment 1.

3.1.3. Materials and design

The materials and design of Experiment 2 were identical to Experiment 1 with the following exceptions. Words were presented equally often in all colours. Thus, “high contingency” and “low contingency” trials were defined by the (false) contingency instructions given at the start of the experiment and not by real contingencies. Which word was assigned to which colour in the instructions was still randomly determined for each participant. Participants were presented with 180 trials selected at random with replacement.

3.1.4. Procedure

The procedure for Experiment 2 was identical to that for participants in the instructed group of Experiment 1.

3.2. Results

3.2.1. Overall

Participants in Experiment 2 did not respond differently to high (565 ms) relative to low contingency (567 ms) trials in response times, $t(52) = .715$, $SE_{diff} = 4$, $p = .478$, $\eta_p^2 < .01$, or in errors (4.9% and 5.1%, respectively), $t(52) = .422$, $SE_{diff} = .4$, $p = .675$, $\eta_p^2 < .01$. Hence, we found no evidence for an instructed contingency effect.

3.2.2. Subjective awareness

A total of 34% (18 of 53) of participants said that they were aware of the presence of colour-word contingencies. Of course, no such contingencies were actually present. Importantly, subjective awareness did *not* matter in this experiment, as there was no difference between subjectively aware and unaware participants in the size of the contingency effect (low minus high contingency trials) in response times, $t(51) = .170$, $SE_{diff} = 8$, $p = .865$, $\eta_p^2 < .01$, or in errors, $t(51) = .389$, $SE_{diff} = .4$, $p = .699$, $\eta_p^2 < .01$.

3.2.3. Objective awareness

Due to a programming error, the first four participants did not have objective awareness data. For the remaining participants, objective awareness of the (instructed) contingencies was high (65%). This guessing was well above chance (i.e., 33%), $t(48) = 6.235$, $SE_{diff} = 5$, $p < .001$, $\eta_p^2 = .45$, indicating that participants as a whole had good memory of the instructed contingency relationships. However, objective awareness was again not related to the size of the contingency effect in response times, $r(47) = -.004$, $p = .976$, or in errors, $r(47) = -.129$, $p = .376$. Subjective and objective awareness were again uncorrelated, $r(47) = .045$, $p = .760$.

3.3. Discussion

Experiment 2 demonstrated that subjective contingency knowledge, at least in the current paradigm, has no direct effect on the size of the contingency effect. Even though a large number of participants claimed that they were aware of the (non-existent) contingency relationships when asked and even though objective awareness measures indicated good memory for the instructed contingency relationships, no contingency learning effect was observed. Furthermore, both subjective and

objective awareness were unrelated to the size of the contingency effect. Thus, it appears that having conscious knowledge about contingency relationships is not sufficient to produce a contingency effect. It seems as if an actual contingency needs to be experienced in order for the contingency to influence behaviour in the present paradigm.

4. Experiment 3

If conscious contingency knowledge does nothing to produce a contingency learning effect directly, then what does it do? An alternative interpretation is that contingency knowledge serves to guide attention to the predictive dimension (in this case, the word). That is, if participants know that the word is predictive of the response, then they may attend more to the identity of the word in order to boost performance. This greater attention to the word will lead to both greater contingency awareness and stronger learning effects. In Experiment 2, this increased attention to the word would not have helped, because contingencies were not present. In Experiment 3, we tested the attention account by giving half of the participants false contingency instruction. Specifically, real contingencies were present, but the instructions told participants of different pairings than those that actually existed. For instance, a participant may have been told that “month” was presented most often in yellow, when it was actually presented most often in red. If contingency instruction only has a beneficial effect on performance by increasing attention to the word and thus causing stronger implicit learning, then these *incorrect* instructions should *improve* a participant’s learning of the *correct* contingencies. The other half of participants did not receive this instruction, similar to the control group in Experiment 1.

4.1. Method

4.1.1. Participants

Fifty Ghent University undergraduates participated in Experiment 3 in exchange for €4.

4.1.2. Apparatus

The apparatus of Experiment 3 was identical to that of Experiment 1.

4.1.3. Materials and design

The materials and design of Experiment 3 were identical to Experiment 1 with the exception that there were only 180 trials selected at random with replacement.

4.1.4. Procedure

The procedure for Experiment 3 was identical to Experiment 1 with the exception that the instructions given to participants in the instruction group were incorrect. That is, the word-colour relationships participants were told were not the correct word-colour relationships. High and low contingency trials were defined relative to the actual contingencies, not the instructed ones. This was also true for the objective awareness data: awareness of the *actual* contingencies was measured.

4.2. Results

4.2.1. Instruction

The response latency and error data for the two instruction groups are presented in Fig. 3. Overall, participants responded significantly faster to high (542 ms) relative to low contingency trials (579 ms), $t(49) = 5.762$, $SE_{diff} = 6$, $p < .001$, $\eta_p^2 = .40$, and also with less errors (4.3% and 7.0%, respectively), $t(49) = 4.051$, $SE_{diff} = .7$, $p < .001$, $\eta_p^2 = .25$. Critically and contrary to our hypothesis, the size of the contingency effect was significantly *smaller* in the instructed group in response times, $t(48) = 2.141$, $SE_{diff} = 12$, $p = .037$, $\eta_p^2 = .09$. Though numerically in the same direction, this difference was not significant in

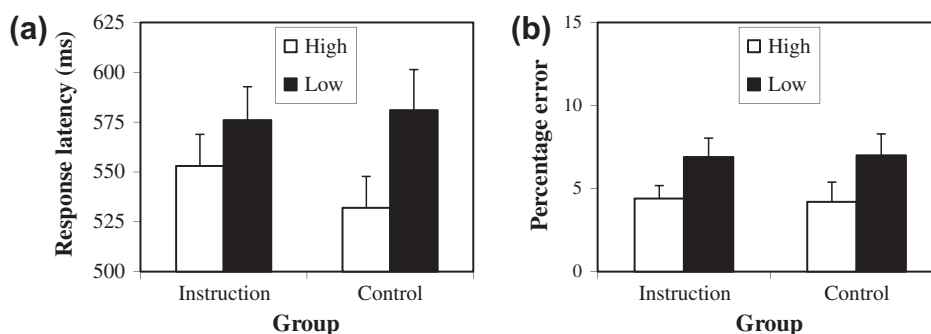


Fig. 3. Experiment 3 (a) response latencies and (b) error percentages as a function of contingency and instruction group. The bars represent standard errors.

the errors, $t(48) = .208$, $SE_{diff} = .3$, $p = .836$, $\eta_p^2 < .01$. Planned comparisons revealed that the contingency effect was significant for instructed participants in response latencies (high: 553 ms; low: 576 ms), $t(24) = 3.147$, $SE_{diff} = 7$, $p = .004$, $\eta_p^2 = .29$, and errors (high: 4.4%; low: 6.9%), $t(24) = 3.216$, $SE_{diff} = .8$, $p = .004$, $\eta_p^2 = .30$. The contingency effect was also significant for control participants in response latencies (high: 532 ms; low: 581 ms), $t(24) = 5.109$, $SE_{diff} = 10$, $p < .001$, $\eta_p^2 = .52$, and errors (high: 4.2%; low: 7.0%), $t(24) = 2.616$, $SE_{diff} = 1.1$, $p = .015$, $\eta_p^2 = .22$.

4.2.2. Subjective awareness

A total of 60% (15 of 25) of participants in the instructed group and 64% (16 of 25) of the participants in the control group said that they were aware of the presence of colour-word contingencies. This one-participant difference was not statistically different, $t(48) = .286$, $SE_{diff} = 14$, $p = .776$, $\eta_p^2 < .01$. It is interesting that instructed participants scored so low on the subjective awareness test, given that the instructions and awareness question were near identical (see Experiment 1 Methods). However, the instructed contingencies did not match the real contingencies, a point which we will return to in the General Discussion. The response latency and percentage error data are presented in Fig. 4. Subjectively-aware participants did not show a significantly larger contingency effect (44 ms) than subjectively-unaware participants (25 ms) in response times, $t(48) = 1.454$, $SE_{diff} = 19$, $p = .153$, $\eta_p^2 < .01$, or in errors (3.1% and 2.0%, respectively), $t(48) = .757$, $SE_{diff} = 1.0$, $p = .453$, $\eta_p^2 = .01$, though both numerical differences were suggestive and consistent in direction with Experiment 1. Subjectively aware and unaware participants were then analysed separately. Subjectively aware participants produced a significant contingency effect in response times, $t(30) = 5.410$, $SE_{diff} = 8$, $p < .001$, $\eta_p^2 = .49$, and errors, $t(30) = 3.475$, $SE_{diff} = .9$, $p = .002$, $\eta_p^2 = .29$. Importantly, subjectively unaware participants also produced a significant contingency effect in response times, $t(18) = 2.505$, $SE_{diff} = 10$, $p = .022$, $\eta_p^2 = .26$, and a marginal effect in errors, $t(18) = 2.068$, $SE_{diff} = 1.0$, $p = .053$, $\eta_p^2 = .19$.

4.2.3. Objective awareness

Participants in the instructed and control groups both scored 88% on the objective awareness task (actual, not instructed contingencies) and did not differ statistically from one another, $t(48) = .006$, $SE_{diff} = 7$, $p = .995$, $\eta_p^2 < .01$. Guessing in the objective awareness test was well above chance (i.e., 33%) in both the instructed, $t(24) = 11.684$, $SE_{diff} = 5$, $p < .001$, $\eta_p^2 = .85$, and control participants, $t(24) = 10.845$, $SE_{diff} = 5$, $p < .001$, $\eta_p^2 = .83$. Objective awareness was marginally correlated with the size of the contingency effect in response times, $r(48) = .239$, $p = .094$, but not in errors, $r(48) = .213$, $p = .137$. Subjective and objective awareness again did not correlate, $r(48) = .125$, $p = .387$. It is again possible, however, that ceiling effects may have reduced these correlations.

4.3. Discussion

We thought that contingency instruction might only serve to guide attention to the predictive word rather than to increase learning in any direct way. However, learning was actually *decreased* in the false instruction condition, rather than increased. Although it may additionally be the case that the false instructions did increase attention to the word, it is clear that learning was impaired. This may mean that contingency knowledge does play some active role in learning that goes beyond merely directing attention to stimuli.

5. Reanalysis 1

In Experiment 3, we thought that giving participants false contingency information would lead to more attention to the word and thus larger contingency effects. Disconfirming this hypothesis, the exact reverse was observed. Reanalysis 1 aimed to test a possible interpretation of the reduced contingency effect for falsely-instructed participants. Specifically, in the analyses already reported in Experiment 3 we assessed the difference between the *actual* high and low contingency trials (i.e., as

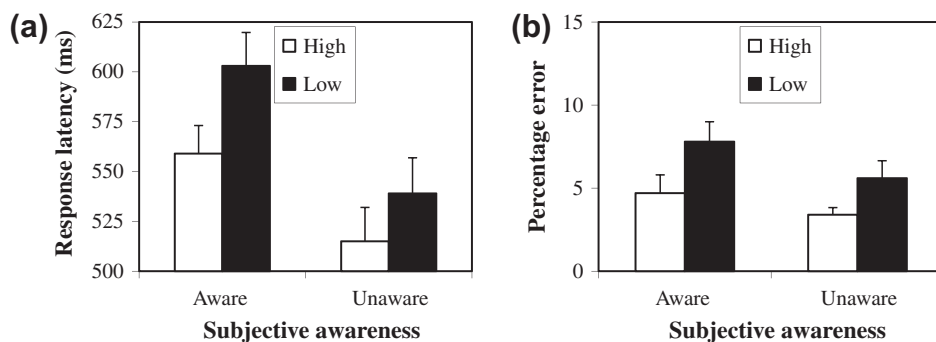


Fig. 4. Experiment 3 (a) response latencies and (b) error percentages as a function of contingency and subjective awareness. The bars represent standard errors.

defined by the pairings), rather than those we instructed. It could be the case that participants in the false instruction group partially learned the instructed contingencies in addition to the actual ones. Indeed, participants may have even been faster and more accurate on trials consistent with the instructions rather than the actual contingencies. Half of the low contingency trials corresponded to the instructed contingencies and half did not. Such a result would indicate that instructions alone can lead to contingency effects. It could also explain why the contingency effect was smaller in the instructed group than in the control group of Experiment 3. If performance is better on low contingency trials that are in line with the instructions than on other low contingency trials, this would reduce the difference between overall performance on the high contingency trials and overall performance on low contingency trials. Thus, in Reanalysis 1 we took a second look at the data of instructed participants from Experiment 3 and considered three types of trials: (1) high contingency trials, (2) instructed contingency trials, and (3) low contingency trials. High contingency trials were those defined by the actual contingencies between words and colours (i.e., frequent trials). Instructed contingency trials were the low contingency trials that were consistent with the (false) instructions. Low contingency trials in this reanalysis were the remaining low contingency trials. Unless indicated otherwise, only participants in the false instruction group of Experiment 3 were included in the analyses because they were the only participants for whom instructed contingency trials could be identified.

5.1. Results

5.1.1. Response latencies

The response latency data are presented in Fig. 5a. Planned comparisons revealed that high contingency trials (553 ms) were responded to faster than instructed contingency trials (577 ms), $t(24) = 3.247$, $SE_{diff} = 7$, $p = .003$, $\eta_p^2 = .31$. More critically, there was no difference in response latencies between instructed contingency trials and low contingency trials (572 ms), $t(24) = .392$, $SE_{diff} = 12$, $p = .699$, $\eta_p^2 < .01$. Furthermore, the 19 ms difference between high contingency and (non-instructed) low contingency trials for instructed participants was still marginally smaller than the 49 ms difference between high and low contingency trials for control participants, $t(48) = 2.000$, $SE_{diff} = 15$, $p = .051$, $\eta_p^2 = .08$. Thus, the response latency data suggest that the decreased contingency effect for instructed relative to control participants is not due to a benefit for instructed contingency trials in the instructed group.

5.1.2. Errors

Although the error effect was not significant in Experiment 3, we nevertheless opted to also assess errors on the three trial types. The error data are presented in Fig. 5b. Although numerically in the same direction as the response latencies, there was no significant difference between high (4.4%) and instructed contingency trials (5.2%), $t(24) = 1.135$, $SE_{diff} = .8$, $p = .268$, $\eta_p^2 = .05$. Interestingly, instructed contingency trials produced less errors than low contingency trials (8.8%), $t(24) = 2.164$, $SE_{diff} = 1.6$, $p = .041$, $\eta_p^2 = .16$. Thus, unlike the response latencies, the error data provide some evidence that participants are (at least partially) biased toward the falsely-instructed contingencies.

5.2. Discussion

Reanalysis 1 aimed to explore whether the smaller contingency effect in the false instruction group could be attributed to a benefit for those low contingency trials that were consistent with the false instructions. The significant difference in response latencies between control and instructed participants could not be explained this way, because instructed contingency trials showed no advantage over low contingency trials. However, an analysis on the errors did reveal that participants were less error-prone in the instructed contingency condition relative to the low contingency condition. This final result suggests that participants did have some bias toward the instructed response, potentially explaining why learning was impaired. This does contrast with the results of Experiment 2, where instructions did not bias participants toward the instructed response. We will return to this point in the General discussion.

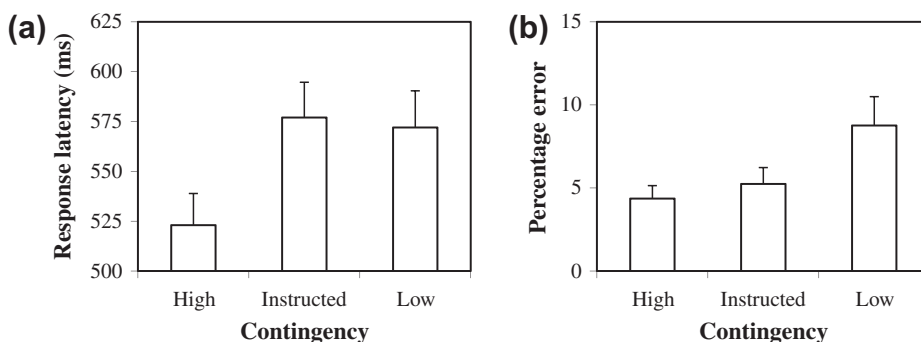


Fig. 5. Reanalysis 1 (a) response latencies and (b) error percentages as a function of contingency type. The bars represent standard errors.

6. Reanalysis 2

Reanalysis 2 aimed to look at the time course of learning in our experiments. Although our past reports have suggested that learning is quite quick and stable (Schmidt et al., 2007, 2010), there are some reasons to suspect a different pattern in the current report. In particular, instructed participants in Experiments 2 and 3 were given faulty information. It is thus possible, for instance, that participants in Experiment 2 initially produced an instructed contingency effect, but then rapidly learned that no contingencies were present and stopped producing the instructed contingency effect. If so, an initially present instructed contingency effect may have simply been lost in the averaging of responses across the whole experiment. Similarly, falsely instructed participants in Experiment 3 might have initially started responding consistent with the instructed contingencies, resulting in very poor performance at first, followed by better learning later on as they discovered the actual contingencies. Thus, the smaller effect for falsely instructed participants could be due solely to poor early performance.

For each of the three experiments, we therefore calculated high and low contingency trials for each block of 30 trials. This led to ten blocks of 30 trials in Experiment 1 and six blocks of 30 trials in Experiments 2 and 3. Particularly in Experiments 2 and 3, we might expect that any changes in the size of the contingency effect for incorrectly instructed participants might occur early on. As a result, we tested for two types of contrasts: (1) a linear trend to capture a potential change over time from the start till the end of the experiment, and (2) a deviation contrast comparing the first block to the mean of the rest, in order to capture a potential sudden shift in performance from the first few trials to the rest of the experiment. For each of

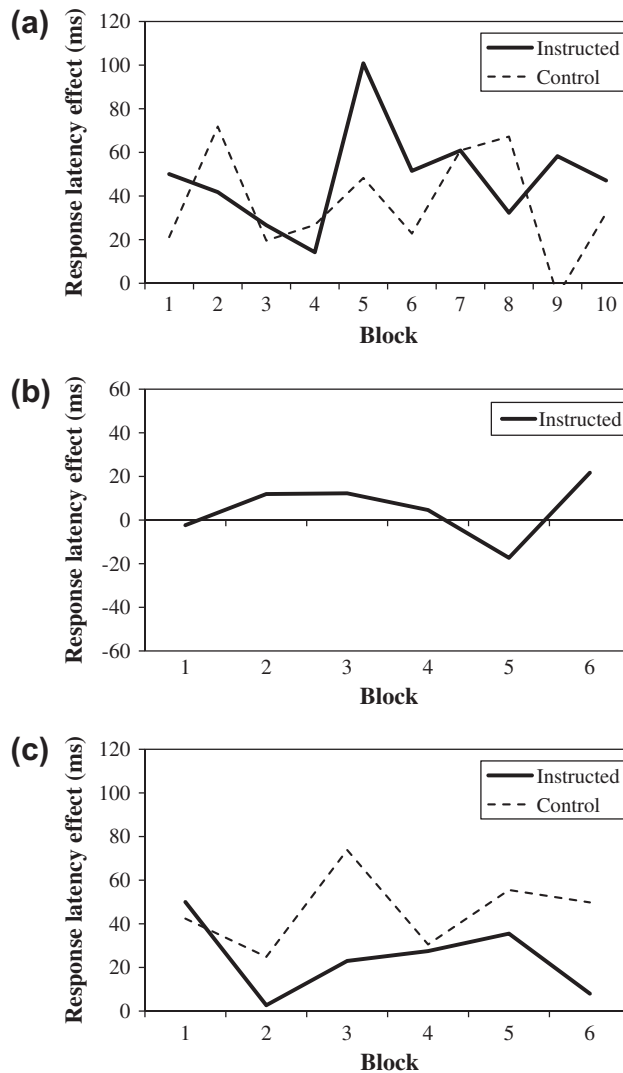


Fig. 6. Reanalysis 2 time series response latency data for (a) Experiment 1, (b) Experiment 2, and (c) Experiment 3.

our three experiments, we thus tested for both linear and deviation trends of block. Errors were too infrequent to be analysed in such small blocks, so only response latencies are reported.²

6.1. Results

6.1.1. Experiment 1

The time series data for Experiment 1 are presented in Fig. 6a. The difference in the learning effect between instructed and control participants in Experiment 1 was not related to block linearly, $F(1,60) = .606$, $MSE = 8788$, $p = .439$, $\eta_p^2 < .01$, indicating that the difference between groups did not grow or shrink with time. The deviation contrast was also not significant, $F(1,60) = .314$, $MSE = 14252$, $p = .577$, $\eta_p^2 < .01$, indicating that the group difference in the first block was similar to the remaining blocks. Although the data are noisy, it appears that the instruction effect appears early and remains stable throughout the experiment.

6.1.2. Experiment 2

The time series data for Experiment 2 are presented in Fig. 6b. The learning effect in Experiment 2 was not related to block linearly, $F(1,52) = .103$, $MSE = 4525$, $p = .749$, $\eta_p^2 < .01$, indicating that the learning effect did not grow or shrink with time. The deviation contrast was also not significant, $F(1,52) = .429$, $MSE = 6914$, $p = .515$, $\eta_p^2 < .01$, indicating no difference in the learning effect in the first block relative to the mean of the rest. Thus, there was no evidence of an early instructed contingency effect.

6.1.3. Experiment 3

The time series data for Experiment 3 are presented in Fig. 6c. Two participants from the control group had to be excluded due to empty cells. The difference in the learning effect between falsely instructed and control participants in Experiment 3 was not related to block linearly, $F(1,46) = .501$, $MSE = 12692$, $p = .483$, $\eta_p^2 = .01$, indicating that the difference between groups did not grow or shrink with time. The deviation contrast was also not significant, $F(1,46) = .623$, $MSE = 16219$, $p = .430$, $\eta_p^2 = .01$, indicating that the group difference in the first block was similar to the remaining blocks. Indeed, the numerical difference is in the opposite direction that one would expect. Like the previous experiments, there appears to be no differential effect of the instructions over time.

6.2. Discussion

Interestingly, no evidence for block effects was found in any of the three experiments. Though chopping the data up into such small blocks made for understandably noisy data, no apparent systematic changes were evident. Thus, the effect of the instruction type appears to be immediate and stable. The immediate effects of contingency learning is consistent with past reports with this paradigm that have revealed learning as early as the first 16 trials (Schmidt et al., 2010; see also, Schmidt et al., 2007). What is particularly interesting about the lack of block effects in the current report is that explicit instructions had a very immediate effect with no apparent changes over time. One might have predicted, for instance, that an instructed contingency effect would have been observed early on in Experiment 2 that disappeared with more learning of the actual (null) contingencies. This was simply not the case, however.

7. General discussion

The primary aim of the present work was to further investigate the relation between contingency learning and contingency awareness using the colour-word contingency learning paradigm. While some past reports have suggested that learning in the colour-word contingency paradigm (and the related flanker contingency paradigm) is not influenced by conscious contingency knowledge (e.g., Schmidt et al., 2007), we pointed out that participants who identify as being subjectively aware might often not actually be contingency aware. We therefore used a more carefully worded subjective awareness question to reduce participant confusion. Also, we avoided floor effects in awareness by using stronger contingencies and instructing some participants about the colour-word contingencies. With 84% subjective awareness in the instruction group and 52% in the control group of Experiment 1, it seems this manipulation was successful. These changes were sufficient to reveal significant effects of subjective contingency awareness. Thus, while high levels of contingency awareness are not typically observed in colour-word contingency learning studies, when participants do have subjective contingency knowledge it does seem to have a positive effect on colour-word contingency learning.

This result provides important new information about the relation between contingency awareness and learning in general because it shows that contingency awareness can matter even in performance tasks in which it is unlikely that participants use conscious knowledge of the contingencies in an intentional manner. In the present task, the contingent distracter

² Considering the distinction between high, instructed, and low contingency trials (i.e., as per Reanalysis 1) would similarly lead to a prohibitively small number of trials in the instructed and low contingency cells. Indeed, 9 of the 25 instructed participants did not have observations in all cells. Though not reported, analysis of the remaining 16 participants provides no different results than what we report below.

is presented simultaneously with the target. Because participants respond on average in about 550 ms, this means that participants have less than 550 ms to process the distracter and to determine the likely response based on the distracter-target contingencies. It is unlikely that participants can engage in these processes intentionally during this short period of time. Nevertheless, subjective awareness of the contingencies does seem to facilitate these processes. Furthermore, these results show how rapidly contingency knowledge can exert an impact on responding.

Although our results shed new light on the relation between contingency awareness and learning, it is important to highlight the fact that subjectively unaware participants did still show a contingency effect in Experiments 1 and 3 and that objective awareness was again found to be unrelated to the size of the contingency effect (though ceiling effects were a possibility). Thus, our results do *not* contradict the notion that contingencies can be learned implicitly. Instead, they merely show that subjective awareness can increase the size of the observed learning effect even in performance paradigms such as the colour-word contingency learning paradigm.

Objective contingency awareness did not correlate with learning. Although this null correlation has been observed elsewhere (e.g., Schmidt & De Houwer, 2012b; Schmidt et al., 2007), we feel this results should be interpreted with caution. In Experiments 1 and 3 (i.e., the experiments in which an objective contingency was present), overall objective awareness was quite high (i.e., near ceiling). When objective awareness is so high, there is too little variability in the measure (i.e., most participants got all three questions correct) to allow a correlation with any variable. Indeed, objective awareness did not even correlate with subjective awareness. The only thing objective awareness was related to was instruction group. That is, it was higher in the instructed relative to control participants in Experiment 1.

Whereas the objective awareness index is designed to capture beliefs about specific contingencies, the subjective awareness question tries to capture beliefs about whether contingencies in general were present in the task. The fact that subjective awareness was higher in the instructed group than in the control group of Experiment 1 thus suggests that contingency instructions led to an increase in conscious acceptance of the presence of contingencies which led to an increase in the size of the contingency effect. From this perspective, the data of Experiment 2 indicate that some participants were fooled into accepting the instructions as factual. The interpretation of the subjective awareness data of Experiment 3 is more complicated. The subjective awareness question asked participants if they believed that contingencies were present. On the one hand, contingencies *were* present. On the other hand, the contingencies that we told instructed participants *were not* present. Thus, for an instructed participant belief in the presence of contingencies and belief in the presence of the *instructed* contingencies were in conflict. This raises the possibility that “subjectively aware” participants in the falsely instructed group were a mix of truly aware and deceived participants. Furthermore, some “subjectively unaware” instructed participants may have been aware of the actual contingencies, but also aware of the fact that the instructions were wrong. Thus, while the contrast between instructed and control participants in Experiment 3 is informative, the comparison of aware vs. unaware participants warrants caution in this one experiment. Overall, the subjective awareness data of all three experiments suggest that an influence of contingency knowledge on learning, at least in the present paradigm, only occurs when a participant has meta knowledge (i.e., is subjectively aware) of the contingencies.

Our experiments not only provide new information about the relation between contingency awareness and learning, they also shed new light on the question of whether contingency information that is given at the outset of the experiment influences learning. Experiment 1 demonstrated a clear effect of contingency instructions on performance, with a 60% larger effect in response times and 116% larger effect in the errors of instructed participants relative to controls. Further analyses demonstrated that instruction group had no effect on performance independent of that attributed to changes in subjective contingency awareness. This might indicate full mediation, though it is possible that a direct effect of instruction group on performance exists, but simply was not significant in our data. At least primarily, it seems that contingency instruction leads to subjective contingency awareness which then leads to a larger contingency effect. Other research has shown positive effects of contingency instruction (usually via “rule” instructions; e.g., Berry & Broadbent, 1984; Reber, Kassin, Lewis, & Cantor, 1980; Strangman, Heindel, Anderson, & Sutton, 2005). Future work is warranted, but our results suggest that the increase in subjective awareness obtained with these sorts of instructional manipulations is what increases learning.

Instructed contingencies do not seem to have a *direct* effect on learning in this paradigm. In Experiment 2, participants were instructed about contingencies that were not actually present in the task. Although many participants claimed that they were aware of the contingencies and objective guessing of the contingencies matched quite strongly with the instructed contingencies, no instructed contingency effect was observed. This reinforces the intuitive notion that the crucial events on trials occur too quickly for explicit contingency knowledge to be used in an intentional way.

The results of Experiment 2 further led us to the notion that contingency awareness might only benefit performance by leading participants to attend more to the predictive dimension (i.e., the word). Indeed, some work (e.g., Jiménez & Méndez, 1999) has suggested that contingency learning is dependent on attention to the predictive dimension, so it is not unreasonable to suggest that explicit contingency knowledge (whether instructed or acquired during the task) can lead to increased attention to the word and thus an increase effect. Based on this idea, we thought that giving participants *false* contingency instructions in Experiment 3 would actually *benefit* performance. Though the instructed contingencies were wrong, it seemed possible that the presence of the instructions would lead participants to more actively look for the contingencies. However, this prediction was wrong. Instructed participants had a significantly *smaller* contingency effect than controls.

The combined results thus suggest that conscious contingency information serves a moderating role on implicit learning: when it matches the actual contingencies implicit learning is improved (Experiment 1), but when it mismatches the actual contingencies learning is impaired (Experiment 3). This fits well with the episodic account of contingency effects discussed

by Schmidt and colleagues (Schmidt et al., 2010). According to this account, information about the distracting word, target colour, and response given are encoded into an episode for each trial (see Logan, 1988). On subsequent presentations of a word, associated episodes are retrieved from memory, leading to a strong bias toward the high contingency response (i.e., because most episodes of a given word will be associated with the high contingency response). Instructed contingencies could be thought of as very strongly encoded episodes. That is, when participants initially memorize the contingencies when given the instructions they make highly accessible episodes linking words to their high contingency responses. Though these episodes might not be enough to produce a contingency effect on their own (Experiment 2), they may be sufficiently strong to positively (Experiment 1) or negatively (Experiment 3) influence the episodic retrieval bias for the high contingency response.

Such episodic traces could have numerous effects on learning. For instance, in Experiment 1 explicit maintenance of correctly-instructed contingency relationships in memory could lead to faster and more reliable implicit retrieval of high contingency responses. Relatedly, explicit processing of stimulus pairs for contingency information could lead to changes in the encoding of trial information. That is, with correct instructions high contingency trials are encoded more strongly as they are consistent with the instructed contingencies, whereas low contingency trials are encoded more weakly as they are inconsistent with the instructed contingencies. As a result, high contingency episodes will be more accessible than low contingency traces, thus leading to stronger episodic memory retrieval for high contingency trials.

This will, of course, backfire when the instructed contingencies are inconsistent with the real contingencies. The instructed contingency trials will be encoded more strongly and the actual high contingency trials less strongly. High contingency trials will still bias the high contingency response (i.e., because of the implicit learning of the *real* contingencies), but the effect will be diluted due to the encoding bias for the wrong (instructed contingency) trials. This explains why the falsely instructed participants did worse than the controls in Experiment 3. The results of Reanalysis 1 provide some support for this episodic account. Instructed contingency trials generated less errors than low contingency trials. Though this effect was only present in the errors, it suggests that participants did have some bias toward the instructed contingency response, thus weakening the benefit for actual high contingency trials.

However, there was no effect of instructions in Experiment 2. This may have to do with the lack of real contingencies in the experiment. When actual contingencies are present (Experiments 1 and 3), correct or false explicit knowledge may be sufficient to, respectively, increase or decrease the retrieval bias toward the (actual) high contingency response (and, in Experiment 3, *decrease* the bias *against* the instructed contingency response). However, when no actual contingencies are present (Experiment 2), the incorrect contingency instructions might still bias encoding of trials that are consistent with the instructions, but this on its own may not generate enough of a retrieval bias for the system to determine an expected response (i.e., the retrieval drift toward the instructed contingency response is not strong enough to exceed the appropriate retrieval threshold). This explains why no instructed contingency effect is present in Experiment 2. In summary, there are multiple means by which subjective contingency awareness may influence contingency learning effects.

A skeptic might argue that an alternative account of the results of Experiments 2 and 3 is that participants began the task in accordance with the instructions, but then eventually discovered that the information given to them was wrong and shifted their strategy. In particular, in Experiment 2 participants would start out using the contingencies to predict responses, but then quickly stop this when it was discovered that the contingencies were not there. Similarly, in Experiment 3 participants would start the task in accordance with the false instructions, only to discover that the instructions were wrong and slowly switch to the correct contingencies (or stop attending to the word). However, the block analyses in Reanalysis 2 do not support this sort of alternative account. The differences between groups did not seem to change across blocks. The episodic account, however, fits well with these rapid effects. If the performance advantage for high contingency trials is due to episodic storage and retrieval processes, then the effect of instructions on said encoding and retrieval processes will be present from the outset of the experiment. This is because the learning rate seems to be extremely fast (Schmidt et al., 2010), with learning effects being driven by only a few of the most recently experienced trials. Thus, the encoding biases due to contingency awareness does not require an aggregation over a large number of trials. Instead, it will be evident immediately.

It is worth reiterating that our finding of an effect of awareness on the learning effect is inconsistent with the findings of Carlson and Flowers (1996; see also, Miller, 1987) using the flanker paradigm. Contingency awareness, measured subjectively, did not increase learning effects when flankers were presented concurrently with the target. Although Type II error is a possibility, it is also notable that their subjective awareness measure was likely equally problematic as the one used by Schmidt et al. (2007). Alternatively, it could be the case that there are inherent differences between the colour-word and flanker tasks contributing to this difference. For instance, distracting words probably have a processing advantage over target print colours in our task, whereas flanking symbols (#, *, and @) probably do not have a processing advantage over the target letters and digits used by Carlson and Flowers. This may explain why conscious contingency knowledge was ineffective in their paradigm but not ours, because it could be that words are processed fast enough to impact colour processing, but symbols are not processed fast enough to impact letter/digit processing. Furthermore, it could be the case that the large number of target stimuli used in their flanker task (viz., 9 letters plus 9 digits for a total of 18 target stimuli) made for too many flanker-target relationships to keep track of. Further research with these two paradigms might thus prove revealing.

Indeed, the experiment of Broadbent et al. (1986) discussed in the introduction suggests that contingency awareness is only beneficial when learning simpler contingencies. It seems that explicit knowledge is only useful when it is simple enough

to keep track of in (limited-capacity) memory. Future work might thus aim to corroborate this by varying the number of contingency pairings to be learned (e.g., three vs. nine word-colour pairs). Future work might also attempt to assess whether the strength of the contingencies involved in the task moderates the role of contingency awareness in learning effects. In the present experiments, the contingencies were quite strong (i.e., words were 80% predictive of the response). With much weaker contingencies (e.g., 50%) participants might be less inclined to use conscious contingency knowledge to anticipate responses, as distracting words would much less frequently predict the correct response. We propose that contingency knowledge is only beneficial to the extent that it is accurately predictive of behaviour. If the contingencies to be learned are too complex, then predictions are likely to be incorrect. Similarly, if false contingency information is instructed (e.g., Experiment 3), then response predictions will also be wrong.

Further support for this notion comes from work on learning goals. Using the highly simplistic colour-word contingency learning paradigm, Schmidt and De Houwer (2012a) gave half the participants the goal to learn contingencies (i.e., they were not told the actual pairings, but asked to discover them). These participants showed a larger contingency effect than controls. Similar goal instructions in more complicated paradigms, such as artificial grammar learning (Reber, 1967), reveal the reverse result. That is, participants given the goal to learn an artificial grammar demonstrated *worse* grammar learning than control participants. In this more complicated task, we suggest that explicit attempts to predict responses will fail, interfering with otherwise-implicit learning effects (for neurological support of this idea see Lieberman, Chang, Chiao, Bookheimer, & Knowlton, 2004). The colour-word contingency learning task, however, is simple enough that response prediction is successful, thus boosting the effect.

The idea that increased difficulty impairs the ability of explicit knowledge to benefit learning is also highly consistent with our episodic account. If the benefit of contingency awareness is that participants use their knowledge of contingencies to more strongly encode the high contingency responses, then this will only aid subsequent retrieval to the extent that participants know the contingencies correctly. If the contingencies are too complex, then participants are likely to have false theories about the relationships between stimuli and responses. Thus, the wrong relations will be encoded more strongly (e.g., as the errors of Experiment 3 in Reanalysis 1 suggest), thus diluting the true contingency effect.

In summary, our paper shows that contingency knowledge can have an effect on the size of the learning effect in the colour-word contingency learning paradigm. This knowledge seems to moderate the strength of implicit learning rather than being used in a direct, intentional manner. Indeed, the time that a participant has to use contingency knowledge between the onset of the stimulus and the response is so short that strategic use seems unlikely. It is therefore interesting that contingency awareness has an effect on performance at all. Our proposed episodic account of contingency learning effects, however, provides an integrative account of our results and other findings in the literature by proposing that explicit knowledge has an effect on performance by influencing how information is encoded into episodes, which then has an impact on subsequent retrieval.

Acknowledgments

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