



Augmentation in contingency learning under time pressure

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Recent research suggests that cue competition effects in human contingency learning, such as blocking, are due to higher-order cognitive processes. Moreover, some experimental reports suggest that the effect opposite to blocking, augmentation, could occur in experimental preparations that preclude the intervention of reasoning mechanisms. In the present research, we tested this hypothesis by investigating cue interaction effects in an experimental task in which participants had to enter their responses under time pressure. The results show that under these conditions, augmentation, instead of blocking, is observed.

For decades, studies on human contingency learning have tried to understand how people learn to predict events in their environment based on the presence or absence of cues that are associated with those events. A common finding is that a participants' tendency to predict an outcome based on the presence of a cue that was previously paired with that outcome also depends on the experience with alternative predictors of that outcome. This principle is well illustrated by a learning effect known as blocking. In a typical blocking experiment, participants are first exposed to some trials in which a cue, A, is paired with an outcome (i.e., A–outcome pairings); then, during a second phase, participants are exposed to trials in which this cue and a novel one, X, are paired with the same outcome (i.e., AX–outcome pairings); finally, in the test phase participants are asked to rate the degree of perceived relationship between X and the outcome. The usual result is that these ratings of the X–outcome association are reduced in comparison to a control condition in which no A–outcome pairings are given during the first phase (e.g., Dickinson, Shanks, & Evenden, 1984). This result shows that the prior training of the A–outcome association reduces the perceived relationship between X and the outcome.

Given that blocking and other cue competition effects have been widely observed in animal classical conditioning (Kamin, 1968; Wagner, Logan, Haberlandt, & Price, 1968), initial demonstrations of these effects in human contingency learning were taken as an evidence supporting the idea that cue competition in contingency learning is based on

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the same low-level associative mechanisms that were invoked to account for classical conditioning phenomena in animal research (Arcediano, Matute, & Miller, 1997; Chapman & Robbins, 1990; Dickinson *et al.*, 1984; Price & Yates, 1993; Wasserman, 1990). However, recent experiments suggest that, contrary to this view, blocking in human contingency learning is based on higher-order cognitive processes related to causal reasoning (De Houwer, Beckers, & Glautier, 2002; Lovibond, Been, Mitchell, Bouton, & Frohardt, 2003; Waldmann & Holyoak, 1992; for a recent review, see De Houwer, 2009). From this point of view, blocking would not be based on a relatively automatic, general-purpose learning process, but instead would reflect a conscious and controlled inferential process by which participants infer that, given that the outcome is the same both when cue X is present (AX-outcome trials) and when cue X is absent (A-outcome trials), X is irrelevant with respect to the outcome.

An interesting prediction that can be drawn from this theoretical interpretation is that blocking should not be observed in experimental tasks that do not allow for the intervention of higher-order cognitive processes. In fact, some experiments show that cue competition is impaired if participants are not allowed to reason. For example, De Houwer and Beckers (2003) showed that blocking is reduced if participants are asked to perform a difficult secondary task simultaneous to the target contingency judgment task (for a similar result, see Waldmann & Walker, 2005). Similarly, Vandorpe and De Houwer (2006) showed that cue competition is not observed when implicit measures are used, suggesting that cue competition is due to some form of reasoning that has no impact on these measures. In a similar vein, other authors have shown that cue competition is reduced or absent when the experimental task uses probe questions that do not request an assessment of the causal relationship between the cue and the outcome (e.g., simply recalling how often the cue and the outcome were paired; see Matute, Arcediano, & Miller, 1996).

Interestingly, a recent experiment published by Mitchell, Lovibond, and Gan (2005) shows that testing procedures that do not involve causal reasoning might give rise not only to an absence of blocking, but even to its opposite effect. In their experiment, participants were exposed to A-outcome pairings intermixed with AX-outcome pairings. The control condition consisted in presentations of B without the outcome intermixed with BY-outcome pairings. When participants were later asked to rate to what extent they thought that X and Y were causally related with the outcome, their ratings were lower for the X-outcome causal relation than for the Y-outcome causal relation. That is, blocking was observed with causal judgments as dependent variable. However, when participants were simply asked to recall which outcome had been paired with X and Y during training, participants made fewer mistakes regarding X than Y. In this case, these responses show *augmentation*: A-outcome pairings improved the recall of the X-outcome relationship. (See also Mitchell, Livesey, & Lovibond, 2007, for a similar dissociation using a different design and procedure).

Most importantly, Mitchell, Lovibond *et al.* (2005) proposed an appealing theoretical interpretation of this dissociation. According to them, their results suggest that both low-level associative mechanisms and higher-order causal reasoning processes take part in contingency learning. In light of many experimental reports showing that reasoning processes are involved in blocking and other cue competition effects (see De Houwer, Beckers, & Vandorpe, 2005), Mitchell *et al.* proposed that the blocking effect found with causal judgments may require the intervention of such higher-order mechanisms. However, the intervention of these processes does

not preclude the possibility that elemental, associative mechanisms are simultaneously encoding the relationship between the cues and the outcomes. Although, as mentioned above, associative mechanisms were first applied to account for blocking, alternative formulations of these models can also account for the opposite effect, augmentation (see Discussion). According to Mitchell *et al.*, the augmentation effect found in their study when causal reasoning was not involved (i.e., in the outcome recall task) might be due to the intervention of these kind of associative processes. Specifically, they proposed that a spread-of-activation model could easily account for their results (with the activation of the X representation at test spreading to the outcome representation both directly and through the X-A-outcome associative chain).

Unfortunately, as acknowledged by Mitchell, Lovibond *et al.* (2005), their data were also compatible with alternative accounts of augmentation. For example, there is no clear reason why the participants' performance on the outcome recall task could not be somehow influenced by inferential processes: participants had time enough to engage in these processes and maybe they also had the motivation to do so. The present experiment aims at providing an additional test for this tentative associative explanation of augmentation. If augmentation is indeed based on low-level associative processes, any limitation in the availability of time to think should favour this effect over blocking. Specifically, augmentation should be readily found in situations in which time pressure precludes the intervention of higher-order processes responsible for blocking and obliges participants to rely on more automatic processes that could potentially yield augmentation.

An additional goal of the present experiment is to find a general procedure suitable for the investigation of this effect in human contingency learning. Although augmentation has received some attention in the animal conditioning literature (Batsell & Batson, 1999; Batsell, Paschall, Gleason, & Batson, 2001; Batson & Batsell, 2000), it is a relatively unknown effect in the human predictive learning domain. As mentioned above, Mitchell, Lovibond *et al.* (2005) found augmentation in humans, but this effect was only observed in a memory task (i.e., an outcome recall task) and, therefore, it is still unclear whether augmentation can be observed in a standard human predictive learning task.

Given that augmentation and blocking can be considered as opposite extremes of the same continuum, we expected that it would be relatively easier to observe augmentation using an experimental task whose features are known to reduce the likelihood of observing blocking. For example, previous research has shown that experimental scenarios in which cues are not perceived as potential causes of the outcomes are less likely to yield blocking (Beckers *et al.*, 2005; De Houwer *et al.*, 2002; López, Cobos, & Caño, 2005; Pineño, Denniston, Beckers, Matute, & Miller, 2005; Waldmann & Holyoak, 1992). Additionally as previously mentioned, blocking and other cue competition effects are reduced if the perceived relationship between cues and outcomes is not assessed by means of a causal judgment (Gredebäck, Winman, & Juslin, 2000; Matute *et al.*, 1996; Pineño *et al.*, 2005). Note that, although these studies have shown that non-causal scenarios and test procedures reduce blocking, none of them has reported that these manipulations produce its opponent effect, augmentation. However, we expected that any manipulation that impairs blocking would also increase the odds of observing augmentation. Therefore in the following experiment, we used an experimental task that did not only induce time pressure but also was framed in such a way that the cues were not perceived as causes of the outcome.

Method

Participants and apparatus

In light of the similarity of results usually found between the laboratory and Internet conditions in other experiments performed with this (Vadillo, Bárcena, & Matute, 2006) and similar experimental tasks (Matute, Vadillo, Vegas, & Blanco, 2007; Vadillo & Matute, 2007b; Vadillo, Miller, & Matute, 2005), the present study was conducted on the Internet, with anonymous participants.¹ Eighty-three visitors of our virtual laboratory (www.labpsico.com) volunteered to take part in the experiment. Random assignment of participants to the two experimental groups resulted in 43 participants in Group 3S and 40 in Group 6S.

All the materials were presented in a HTML document which included JavaScript functions to manage the presentation of the stimuli on the screen and to collect participants' responses. All the stimuli involved in the experiment were preloaded in the computer's memory before participants could start the experiment, so that differences in the connection speed did not influence the pace of the experiment.

Procedure and design

The experiment was conducted with a preparation and cover story that had already been used in several experiments performed in our laboratory (for a detailed description of the task and instructions, see Pineño & Matute, 2000). Participants were asked to imagine that they were soldiers whose task was to rescue some refugees that were hidden in a ramshackle building. On each trial, participants were given the opportunity to place a number of people in a truck and to take them to a safe place. Participants could enter people into the truck by pressing the space bar repeatedly. Participants could also enter larger numbers of people into the truck by keeping the space bar pressed instead of pressing it repeatedly. However, the refugees placed into the truck did not always arrive safely at their destination. On some trials, the road the truck had to move through contained mines that could explode. Participants could predict whether or not the road would be mined on a given trial by paying attention to a spy radio installed in the truck. Certain colours in the spy radio predicted that the road would be safe (and, therefore, that participants should place as many refugees as possible into the truck), whereas other colours predicted that the road would be mined (and, therefore, that participants should avoid placing refugees into the truck during those trials). Participants were not told which lights predicted which outcome but they could learn this throughout the learning phase by paying attention to what happened after the presentation of each colour. Thus, the number of refugees placed in the truck on each trial when the light was on was taken as an index of the extent to which participants had learned that the cue (i.e., the colour light) presented on that trial predicted that the road would be safe. Participants earned one point for each refugee placed in the truck on the trials in which the road was safe and lost one point for each refugee placed in the truck on the trials in which the road was mined. Importantly, participants could only decide whether or not to put people in the truck and enter their responses during the brief interval in which the colour lights were present on each trial. This feature of the

¹ Apart from these studies, an additional experiment conducted simultaneously in the laboratory and on the Internet with an experimental task identical to that of Group 3S in the present experiment confirmed that an augmentation effect of comparable size could be found in both settings (Vadillo & Matute, 2007a).

experimental preparation allowed us to manipulate the time pressure of the task (see below). Participants were not asked to respond quickly after the onset of the colour lights. However, the sooner they began to respond, the more people they could put in the truck while the light was on, with no upper limit in the number of refugees that could be placed into the truck on any given trial (except for the one imposed by time limitation itself).

Augmentation was assessed using a within-subjects design. During Phase 1, participants were exposed to two types of trials. In one of them (A-outcome1 trials), one colour was presented in the spy radio predicting that the road was safe and that it was possible to save refugees by pressing the space bar. On the remaining trials (C-outcome2 trials), a different colour was presented in the spy radio predicting that the road would be mined and that refugees placed in the truck would not arrive safely at their destination. During this phase, participants were exposed to 16 A-outcome1 trials and 8 C-outcome2 trials in pseudo-random order. During Phase 2, participants were exposed to three types of trials. On AX-outcome1 trials the colour that previously had predicted the opportunity to save people was presented in compound with a novel colour and this compound cue was also followed by the opportunity to save refugees. On BY-outcome1 trials, participants were exposed to the compound presentation of two novel colours that also predicted the opportunity to save refugees. Finally, some additional C-outcome2 trials were included during Phase 2. During this second phase, participants were exposed to 4 AX-outcome1 trials, 4 BY-outcome1 trials, and 8 C-outcome2 trials in pseudo-random order. In both phases, the inter-trial interval was random, ranging from 3 to 7 s. The colours that served as A, B, X, and Y were blue, yellow, red, and green, all counterbalanced in a Latin square. Colour C was purple for all participants. After the training sequence of trials, cues X and Y were presented on two test trials (counterbalanced for order) in which participants were given no feedback. More responding to cue X (whose associated cue, A, had already been paired with the outcome in Phase 1) than to cue Y (whose associated cue, B, had never been paired with the outcome before compound training) was indicative of augmentation.

As a means to check the role of time pressure on augmentation, the availability of time to respond was explicitly manipulated. For half of the participants (Group 3S), the colour cues were presented for 3 s on each trial. For a second group of participants (Group 6S), the cues were presented for 6 s, so that they had more time to decide whether or not to enter many responses and to act accordingly. The time pressure was not manipulated with more extreme values (e.g., with 1 vs. 10 s or with an unlimited amount of time), because with less than 3 s the task would have been very difficult to accomplish and with more than 6 s it would have resulted too easy and boring, which would have introduced an undesired motivational confound in the manipulation.

Results

As is always done in our laboratory and in order to assure that participants were paying attention to the experimental task, two data selection criteria were used. First, we removed from the sample the data from participants who responded less on the last A-outcome1 trial than on the last C-outcome2 trial of Phase 1, which was indicative of poor or null learning of the relationship between each cue and its corresponding outcome. Second, for the same reason we also removed the data from participants who responded less on the last AX-outcome1 trial or BY-outcome1 trial

than in the last C-outcome2 trial of Phase 2. Eight participants (four in each group) failed to meet these data selection criteria and were removed from the subsequent analyses.

The mean number of responses to cues X and Y at test is shown in Table 1. However, as participants in each group had different amounts of time to enter responses, the absolute number of responses on all trials is not a valid dependent variable in this experiment, given that the number of responses is necessarily much larger in Group 6S than in Group 3S. Additionally, exploratory analyses showed a large within- and between-groups variability in the general level of responding during training trials as well as during test trials, which precluded the use of standard statistical analyses. In order to increase the comparability of the dependent variable between Groups 3S and 6S and to reduce the variability in the data, a relative measure of responding was computed by dividing the number of responses during test trials by each participant's number of responses in the last A-outcome1 trial of Phase 1. We decided to use responses during the last A-outcome1 trial as a baseline because after the extended training with A during Phase 1 participants were responding at a high and stable rate. The mean number of responses given during the last A-outcome1 trial were 52.05 ($SEM = 2.91$) and 130.81 ($SEM = 5.66$) in Groups 3S and 6S, respectively.

Table 1. Absolute number of responses at test

	X		Y	
	Mean	SEM	Mean	SEM
Group 3S	37.54	4.38	29.36	3.61
Group 6S	75.75	11.1	81.75	10.66

The computed measures of responding to X and Y at test in both groups are depicted in Figure 1. As can be seen, in Group 3S the level of responding is higher for X than for Y, indicating an augmentation effect under time pressure conditions. However, in Group 6S responding to X and Y is rather similar, which indicates that the augmentation effect disappeared when more time to respond was available. A 2 (Cue: X vs. Y) \times 2 (Group: 3S vs. 6S) mixed ANOVA performed on the relative indices of responding at test showed a significant Cue \times Group interaction, $F(1, 73) = 5.21$, $MSE = 0.08$, $p < .05$. The main effects of Cue and Group failed to reach statistical significance, $F(1, 73) = 1.96$, $MSE = 0.80$, $p = .16$, and $F(1, 73) = 1.65$, $MSE = 0.35$, $p = .20$, respectively. Planned comparisons showed that, as expected, responding to X at test was significantly higher than responding to Y at test in Group 3S, $t(38) = 2.23$, $p < .05$. However, in Group 6S the difference in responding to X and to Y at test was non-significant, $t(35) = 0.83$, $p = .41$. Therefore, the augmentation effect was found in Group 3S but disappeared in Group 6S due to the increased availability of time to respond.

Discussion

Our results show that augmentation can be found in a contingency learning task and that this effect is highly dependent on time pressure. Although no cue interaction effect

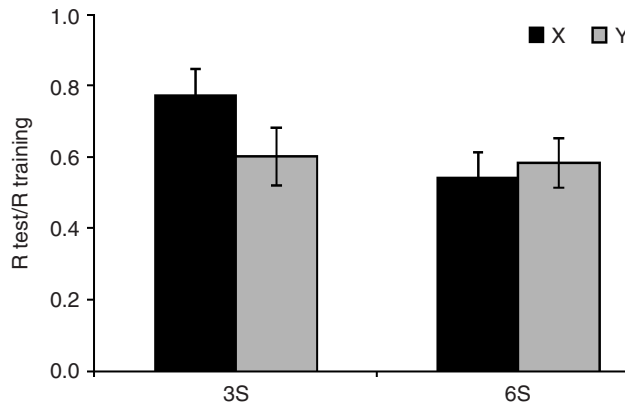


Figure 1. Mean relative responding to cues X and Y at test for participants in Groups 3S and 6S. This relative measure was computed by dividing the absolute number of responses to X and Y at test by the number of responses on the last A–outcome1 training trial. Error bars denote standard errors of the means.

was observed when participants had 6 s to decide how to act on each trial, as the availability of time was reduced, a significant augmentation effect arose. This speeded situation is likely to encourage the use of a different strategy. Instead of relying on time consuming and effortful reasoning processes, participants in Group 3S were probably obliged to rely on more automatic processes.

It could be argued that the 3-s time window is wide enough for higher-order cognitive processes to take place. However, if the augmentation effect was due to some kind of reasoning process, then one would expect, if anything, more augmentation when participants have more time to enter their responses. Contrary to this prediction, augmentation not only became smaller as the time pressure was reduced, but even vanished in the 6S group. The manipulation of time availability has been frequently used in the past to decide whether certain psychological processes are due to low level, automatic mechanisms or to higher-order, cognitive processes (Fazio, Sanbonmatsu, Powell, & Kardes, 1986; Lamberts & Kent, 2007). Following this general strategy, the sensitivity of augmentation to the time pressure manipulation suggests that this effect is better understood in terms of automatic processes. A similar conclusion was recently reached by Karazinov and Boakes (2007), who observed that second-order conditioning (another effect opposite to cue competition) takes place only under time pressure.

In our opinion, these results provide support to the account of augmentation provided by Mitchell, Lovibond, *et al.* (2005). As mentioned above, these authors found a dissociation between causal judgments and outcome recall judgments. When participants were asked to rate the strength of the causal relation that they perceived between the cues and the outcomes, blocking was observed. However, when they were simply asked to recall the outcome that had been paired with each cue, augmentation occurred. In consonance with many recent findings that suggest that cue competition is mediated by higher-order cognitive processes (see De Houwer *et al.*, 2005), Mitchell, Lovibond, *et al.* (2005) argued that their results could be understood by assuming that causal judgments were mainly determined by inferential reasoning. By contrast, the augmentation effect found in outcome recall would, from their point of view, be due to

a much more automatic process. Although they did not directly test this hypothesis, the results found in the present experiment give support to their theoretical proposal.

Although the results of this experiment, together with those of Karazinov and Boakes (2007) and Mitchell, Lovibond *et al.* (2005), suggest that augmentation can be better understood in terms of low-level mechanisms, they are silent in relation to the specific nature of these mechanisms. Mitchell *et al.* proposed that augmentation could be explained in terms of a spread-of-activation process. From this point of view, the outcome recall would be determined by the net activation of the outcome. The outcome would not only be activated by virtue of the association between the target cue and the outcome (X-O), but also due to the activation spreading from the target cue to its associated cue and from the associated cue to the outcome (X-A-O). According to this account, the training of the associated cue with the outcome would enhance the activation of the outcome at the time of test and, therefore, augmentation should be observed. This type of explanation has already been explored in the area of animal conditioning (e.g., Durlach & Rescorla, 1980) and has been implemented in several formal models of associative learning (e.g., Pineño, 2007; Stout & Miller, 2007).

However, there are alternative explanations for the augmentation effect. For example, it could be argued that the presence of an already well-trained predictor of the outcome (or simply an already familiar cue) during X training, makes X attract more attention than Y, which would result in improved learning of the X-outcome association.² Alternatively, the effect could be explained in configural processing terms (Pearce, 1994, 2002) by assuming that the compound cues AX and BY are processed as whole configurations (not as simple combinations of their elements), and that there is good generalization between the representations of A, AX, and X at test, which would also result in improved recall of the outcome relative to the control cue Y (see Urcelay & Miller, 2009, for a recent exploration of the role of this mechanism in potentiation in animal conditioning). Moreover, this effect might be accounted for by means of a non-associative mechanisms operating on episodic memory retrieval: participants trying to recall which outcome was paired with X might incidentally recall that cues X and A were also presented together and that A had been consistently paired with the outcome. Although this memory process might not be associative, it would still be an automatic, low-level mechanism, unrelated to the inferential reasoning processes assumed to sometimes operate on contingency learning. Neither our results nor those of Mitchell, Lovibond *et al.* (2005) allow us to discriminate among these competing accounts of augmentation.

It should also be noted that in spite of our augmentation effect being better explained in terms of elemental, associative (or episodic memory retrieval) processes, under different circumstances it might be possible to observe an augmentation effect based on completely different mechanisms. In fact, a series of experiments conducted by Mitchell, Killeddar, and Lovibond (2005) suggest that participants can be 'taught' to show augmentation (instead of blocking) by pre-training them with cue combination rules different from those that implicitly give rise to blocking. For example, if participants are first taught that the two elements of a reinforced compound, F and G, must have the same associative status (i.e., if they are exposed to F-outcome pairings,

² Note, however, that current attentional models of associative learning (e.g., Mackintosh, 1975) are designed to explain the opposite result, blocking, and therefore predict that cues presented together with already well-established predictors of the outcome tend to receive less attention.

G–outcome pairings, and FG–outcome pairings), then when presented with AX–outcome and A–outcome trials, they will also tend to predict the outcome in the presence of X (i.e., augmentation). Given that this result is probably based on some kind of analogical reasoning or rule learning, it is unlikely to be representative of the kind of processes responsible for the augmentation effect found in the present experiment which only occurred under time pressure.

The results here presented shed light on the processes involved in cue interaction effects by showing that augmentation can be observed and is (at least sometimes) better explained in terms of low-level processes. However, these results are silent regarding the nature of its opposite effect, the extensively investigated blocking effect. As mentioned in the introduction, blocking has been explained both in terms of high-order reasoning processes and in terms of associative processes. Although many experimental findings are compatible with the former point of view (see De Houwer, 2009, for a review), there are also many demonstrations of blocking and cue competition effects that are rather difficult to explain in terms of reasoning processes (e.g., Le Pelley, Oakeshott, & McLaren, 2005; Mitchell, Lovibond, Minard, & Lavis, 2006). Moreover, blocking was originally found in animal conditioning experiments (Kamin, 1968), suggesting that the blocking effect can be observed even in the absence of sophisticated cognitive processes. All this evidence indicates that blocking is a complex effect that can be attributable to different mechanisms (associative or higher order) under different circumstances, depending on the characteristics of the experimental task, such as the causal scenario, the testing procedures, the complexity of the task, and so on. The results of the present experiment suggest an even more complex situation: theories of human contingency learning should not only account for cue competition effects, such as blocking, but also for cue facilitation effects, like augmentation. The study of the conditions under which blocking and augmentation are observed and the potential dissociations between both effects will help us gain a deeper insight into the still obscure mechanisms involved in contingency learning.

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