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Backward Blocking and Interference between Cues are empirically equivalent in non-causally framed learning tasks

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Abstract

Backward blocking (BB) and interference between cues (IbC) are cue competition effects produced by very similar manipulations. In a standard BB design both effects might occur simultaneously, which implies a potential problem to study BB. In the present study with humans, the magnitude of both effects was compared using a non causal scenario and a within subjects design. Previous studies have made this comparison using learning tasks framed within causal scenarios. This posits a limit to generalizing their findings to non-causal learning situations because there is ample evidence showing that participants engage in causal reasoning when tasks are causally framed. The results obtained showed BB and IbC effects of the same magnitude in a non causal framed task. This highlights the methodological need for an IbC control in BB experiments.

Acknowledgements

Support for this research was provided by Grant SEJ2007-63691/PSIC from Dirección General de Investigación of the Spanish Government, Grants SEJ-406 and SEJ-03586 from Junta de Andalucía, and Grant PI2008-9 from the Basque Government. David Luque and Joaquín Morís were supported by F.P.D.I. fellowships from Junta de Andalucía. We would like to thank Francisco J. López and Miguel A. Vadillo for their insightful comments on this experiment. Correspondence concerning this article should be addressed to Pedro L. Cobos, Departamento de Psicología Básica, Campus de los Teatinos, Universidad de Málaga, 29071, Málaga, Spain, or to Helena Matute, Departamento de Psicología, Universidad de Deusto, Apartado 1, 48080 Bilbao, Spain. E-mail: p_cobos@uma.es or matute@deusto.es.

Backward Blocking and Interference between Cues are empirically equivalent in non-causally framed learning tasks

Backward Blocking (BB hereafter) and Interference between Cues (IbC hereafter) are two learning and memory phenomena with many similarities regarding the standard experimental conditions in which they are observed. In a BB design, a compound of two cues, A and B, is first paired with an outcome. Later on, one of the elements of the compound, B, is presented repeatedly with the same outcome (i.e., AB→O1 followed by B→O1). When the other element of the compound, A, is subsequently tested, it elicits a lower response than if participants had not been exposed to B→O1 pairings (e.g., Shanks, 1985). Similarly, in an IbC design, a cue, A, is paired with an outcome, and, later on, another cue, B, is trained with the same outcome (i.e., A→O1followed by B→O1). As in the case of backward blocking, when Cue A is then presented at test, participants' responses are weaker than in a control group not exposed to B→O1 pairings (e.g., Matute & Pineño, 1998). Thus, in both phenomena the B→O1 relationship learned during the second stage reduces the expression of the previously learned relationship between the absent cue, A, and the outcome. Thus, at the empirical level, the only difference between them is whether the two cues receive compound training during Stage 1.

This apparently slight difference is a crucial one because, according to the theoretical accounts of BB, training Cues A and B in compound is a necessary condition to observe a BB effect (e.g., Aitken, Larkin, & Dickinson, 2001; Dickinson & Burke, 1996; Stout & Miller, 2007). Thus, if the decrease observed in responses to A were found without presenting A and B together during the first training phase, as in an IbC experiment, such effect could not be taken as a case of BB. As a consequence, to infer a BB effect it should be empirically shown that the compound training of a BB design adds something to the mere separate training of an IbC design. In other words, as a methodological requirement, the experimental evidence for BB should be based on the comparison between BB and IbC in the same experiment. In case of a greater impact of the BB preparation, a true BB effect can be inferred.

However, because IbC is a relatively recent phenomenon in human contingency learning, and has only been studied in very few laboratories, researchers working on BB have rarely used an IbC control condition in BB studies. Thus, BB has been inferred in many BB studies despite not having provided any evidence supporting the causal role of compound training of cues. This leads us to the conclusion that many, or at least, some of the so-called BB effects found so far could actually be cases of IbC.

To our knowledge, there are only two studies comparing BB and IbC in the same experiment. In one of them, Vadillo, Castro, Matute, and Wasserman (2008) observed a significantly larger effect of BB than of IbC. The authors interpreted this difference as evidence of a true BB effect which would be different from an IbC effect. Similarly, Escobar, Pineño, and Matute (2002) found significant effects of BB and IbC. However, they reported no difference in size between BB and IbC, which was interpreted as evidence of similar processes underlying both.

The fact that the instructions used in both experiments suggested a causal interpretation of the relationships between cues and outcomes makes it difficult to extrapolate the results to non-causal learning situations. There is considerable evidence showing that learners engage in causal reasoning processes when the learning tasks are framed within causal scenarios (e.g., Waldmann & Holyoak, 1992). Also, it has been shown that in such circumstances both BB and IbC are modulated by the causal direction of the learning task (Booth & Buehner, 2007; Cobos, López, & Luque, 2007). Specifically, BB is observed when learning occurs in the predictive causal direction (i.e., when the event presented first in each learning trial –the cue- is described as the cause which produces the event presented subsequently –the outcome). However, BB reduces or disappears when learning occurs in the diagnostic causal direction (i.e., when the cue and the outcome are interpreted as the effect and the cause, respectively). Conversely, IbC is observed in the diagnostic but not in the predictive causal direction.

Thus, an important implication of those results is that the inconsistency between Vadillo et al.'s (2008) and Escobar et al.'s (2002) results can be explained by a causal reasoning account of BB and IbB. Specifically, participants in Vadillo et al.'s (2008) experiment learned in the predictive direction because the learning task was framed within a predictive causal scenario in which the cues were described as causes and the outcomes as effects. In this scenario, participants were instructed to imagine that they were allergists that had to investigate which foods caused certain allergic reactions in one of their patients. In each trial, the foods (causes) were presented first and were followed by the allergic reactions (i.e., effects presented as outcomes). Therefore, the participants learned in the predictive causal direction. Thus, according to the causal reasoning account, BB but not IbC should be observed. In fact, Vadillo et al. (2008) found a greater effect of BB than of IbC, the latter being rather small. This difference was not observed in Escobar et al.'s (2002) experiment in which the instructions suggested a diagnostic causal interpretation of the learning task. In this case, the participants were instructed to imagine that they had to help a group of refugees to escape from a war zone in several trucks. In this task, the cues were light indicators that signalled the presence or absence of several obstacles (e.g., hidden mines) on the road which played the role of outcomes (see also Pineño, Ortega, & Matute, 2000). Thus, participants had to infer whether there were obstacles, as hidden mines, on the road, from the illumination of indicator lights to decide whether to place or not refugees in the trucks. Though the instructions did not explicitly state the causal status of the events, the diagnostic interpretation seems very likely given that people are very familiar with the existence of mine detectors and devices that can detect metals or other sort of materials. In any case, it is very unlikely for participants to have attributed any causal power to the illumination of the lights to produce the different obstacles on the road (see Cobos et al., 2007, and Luque, Cobos, & López, 2008, for further details on the causal interpretation of these scenarios).

The considerations above raise an interesting question, namely what would be the case if BB and IbC were tested in a neutral situation in which none of them is promoted over the other by suggesting either a predictive or a diagnostic causal interpretation of the learning task. Testing this idea was therefore the aim of the present study. Thus, in the present experiment we compared BB and IbC in a situation in which the instructions suggested arbitrary, non-causal, relationships between cues and outcomes. It is important to note that, in the context of human causal learning, a positive contingency between a cue and an outcome does not imply a causal relationship between both events. Indeed, it has been shown that human beings are capable of differentiating between mere contingent relationships and causal relationships (see, e.g., Cheng, 1997) as well as between predictive and causal relationships (e.g., Vadillo & Matute, 2007). Therefore, in the present research we used colored rectangles as cues and plants as outcomes in order to make sure that the relationship between them was arbitrary. The words “cues” and “outcomes” are therefore used only here just to denote the event presented first (cues: colored rectangles) and the event presented second (outcomes: plants), without any reference to any potential causal relationship between them. Moreover, although our task included cues and outcomes with a positive contingency, the instructions presented to the participants did not use any of these words (causes, effects, cues, outcomes) and did not suggested any causal role for the events. Thus, we used a simpler situation to help draw clearer conclusions about the magnitudes of BB and IbC effects without the potential confound of causal interpretations.

(Table 1 about here)

Method

Participants and apparatus

Forty-two psychology students from the University of Deusto volunteered for this study. The experiment was run in a computer room with capacity for sixty participants keeping one-meter distance from each other. The task was performed on personal computers equipped with home-built software written in Visual Basic 2005 (Microsoft, USA) with the participants responding via the keyboard. The horizontal distance between the participants’ head and the monitor was, approximately, 120 cm.

Procedure

The design of the experiment is shown in Table 1. During Phase 1, the participants saw three compound cues (AB, CD and EF) that were paired with three outcomes (O1, O2 and O3, respectively). Each type of trial in Phase 1 was presented 20 times in pseudorandom order (i.e., avoiding more than two consecutive trials of the same type). During Phase 2, the participants were exposed to 15 B-O1 trials pseudorandomly intermixed with 15 G-O3 trials. BB of Cue A should be observed because, during the first phase, A was always compounded with a competing cue, B, which, during the second phase, was followed by the same outcome (O1). G was a new cue that was presented only during Phase 2 and which shared the outcome with the compound cue EF, as in an IbC design. Therefore, IbC should be observed when testing either E or F because none of these cues had been trained in compound with G. The compound cues C and D, and the corresponding outcome, O2, were not presented in Phase 2 and therefore both C and D could serve as overshadowing controls. In the test phase, Cues A, C, and E were presented only once per participant in counterbalanced order. It is important to note that the manipulation was within-subject, hence, all participants performed the three experimental conditions: BB, IbC as well as the overshadowing control condition (see Table 1).

The procedure of the experiment was similar to that in Luque, Morís, Cobos and López (2009) study. First, participants read the instructions and had the opportunity to ask questions. The participants could earn points by betting on each trial. In order to do so, they had to learn the relationships between some coloured rectangles and some fictitious plants which played the role of cues and outcomes, respectively (an English translation of the task instructions are given in the Appendix section). The coloured rectangles were blue, brown, yellow, orange, red, green, and pink, and their role as the abstract cues shown in Table 1 were counterbalanced. The plants were pictures of fictitious plants labelled as Kollin, Dobe, and Yamma, and their role as the abstract outcomes shown in Table 1 were also counterbalanced. The response options were randomly placed at the left, middle, and right bottom of the screen on a trial-by-trial basis. For this reason, the first thing to occur immediately before each trial was the display of the three possible random response options, one per outcome, consisting of the labelled plant photos. This was done so that participants could know, before the current trial started, which key should be pressed during that trial for each of the three possible outcomes. Under each response option, a scroll bar, together with a text box, was displayed to indicate the amount of points the participant was betting for the corresponding option in each trial. Then, the cue, or cues, (i.e., one or two of the coloured rectangles) appeared at the middle top of the screen for 2.5 s during which the participants had to bet which of the three plants they thought was related with the cue (or cues) that were present in the screen in that trial. When two cues were displayed on the same trial, they were placed one beside the other, the specific location for each one being counterbalanced on a trial-by-trial basis. Once the 2.5 s time had passed, the cue (or cues) disappeared, which was indicated by the rectangle (or rectangles) taking on the grey colour (see Figure 1). To respond, the participants placed their bets by pressing either Key “1”, or Key “2”, or Key “3” for the plant (i.e., the response option) placed at the left, middle, or right bottom of the screen, respectively. While a given response key was kept pressed, the points bet for the corresponding option increased continuously, which was indicated analogically, by the movement of the scroll-bar from left to right, as well as with numbers in the corresponding text box ranging from 0 to 100. Once the cue had disappeared, pressing any of the response keys had no effect on the amount of points bet. On each trial, participants earned as many points as those bet for the correct outcome, and lost as many points as those bet for an incorrect outcome. After each bet, feedback was given consisting of: a) the correct plant, which was indicated by keeping it visible, and removing the remaining ones from the screen, b) the amount of points earned on a given trial, which was indicated in a text box placed on the centre of the screen over the labelled plant photos, and c) the total points gained throughout the training trials, which was indicated in a text box at the right top of the screen.

The test phase consisted of additional trials which only differed from the previous training trials in two respects: cues were presented for 5s, and the participants received no feedback after their bets.

(Figure 1 about here)

Analysis

To make sure that the data corresponded to participants who had understood the instructions and paid attention to the task, their total scores were first descriptively analyzed. The data from those participants whose total score at the end of the two learning phases were two standard deviations below or above the mean of the whole sample were removed. Using this criterion two participants that scored two standard deviations below the mean were excluded from the analysis. In addition, due to a software error, the data from six participants were also removed from the analysis. The test phase for these participants included two Cue C trials and no Cue A trials. Thus, we could not collect data regarding the BB condition from these participants. All the statistical analyses were performed for the remaining participants (N = 34). The dependent measure for these analyses was the number of points bet on the correct outcome in test trials -e.g., in the test for BB, the dependent measure was the number of points bet on Outcome O1 (see Table 1). As an additional dependent measure, we calculated the accuracy of responses in each condition, i.e., the percentage of correct responses.

Results

As shown in Figure 2, responding to Cue E was weaker than responding to Cue C, which suggests that IbC was found. BB is also evident in that responding to Cue A was weaker than responding to Cue C. Moreover, both the BB and the IbC effects seemed to be of similar size. A repeated measures ANOVA performed on participants' responses at test confirmed these impressions, revealing a significant effect of cue (A, C, E), $F(2, 66) = 5.03$, $MSE = 1609.5$, $p = .009$, $\eta^2 = 0.13$. Least Significant Difference (LSD) pairwise comparisons showed a significant IbC effect (cue E vs. C, $p = .019$, $\eta^2 = 0.16$) as well as a significant BB effect (cue A vs. C, $p = .002$, $\eta^2 = 0.24$). Finally, no differences were detected between both effects (cue A vs. E, $p = .630$, $\eta^2 < 0.01$).

Additionally, we repeated the same analysis with another dependent variable in which the accuracy of responses was also assessed. To achieve this aim, we analyzed the percentage of correct responses at test in each experimental condition. The percentage of correct responses was 53.79%, 52.14% and 81.33% for the conditions IbC, BB and Overshadowing, respectively. Also, a repeated measures ANOVA was performed on participants' percentage of correct responses at test, revealing a significant effect of condition (IbC, BB, Overshadowing), $F(2, 66) = 4.28$, $MSE = 2134.5$, $p = .018$, $\eta^2 = 0.12$. LSD pairwise comparisons showed the same pattern than in the previous analysis, i.e., a significant IbC effect (IbC vs. Overshadowing, $p = .013$, η^2

= 0.17), a significant BB effect (BB vs. Overshadowing, $p = .005$, $\eta^2 = 0.21$), as well as no differences between the IbC and the BB conditions ($p = .9$, $\eta^2 < 0.01$).

(Figure 2 about here)

Discussion

BB and IbC are very similar effects that are usually accounted for by very different associative accounts. In both cases, responding to the target cue is reduced by later pairings of an alternative cue with the same outcome. The only difference between both effects is that, while BB requires that the target and the alternative cue be previously trained in compound, IbC is found when both cues are trained apart (see Table 1). Interestingly, although to infer a true BB effect it is necessary to empirically show that training cues in compound makes a difference compared to a mere IbC preparation, this has been rarely taken into account for control purposes in BB experiments.

To our knowledge, the use of an IbC control in BB experiments has only been carried out in two previous studies in which BB and IbC were compared in the same experiment (Escobar et al., 2002; Vadillo et al., 2008). Whereas BB was found to be significantly greater than IbC in Vadillo et al. (2008), Escobar et al. (2002) reported observing BB and IbC effects of similar magnitude. However, both experiments were based on learning tasks framed within causal scenarios that could have made participants engage in causal reasoning processes. In fact, as explained in the

Introduction, the difference between Vadillo et al.'s (2008) and Escobar et al.'s (2002) results is consistent with a causal reasoning account of BB and IbC if we assume that participants learned in the cause-effect direction in the former case, and in the effect-cause direction in the latter case (Booth & Buehner, 2007; Cobos et al., 2007). Thus, the results found so far cannot be straightforwardly extrapolated to human contingency learning situations in which no causal scenario is used, and, thus, no effect is promoted over the other on the basis of causal reasoning processes.

As in previous studies, the present study used a design intended to compare BB and IbC in the same experiment. Unlike previous experiments our task instructions did not suggest any causal interpretation of the learning task. Thus, the use of causal reasoning processes was prevented because such mechanisms are only evoked in situations that are clearly interpretable as causal (Lopez, Cobos, & Caño, 2005).

Our results showed a significant effect of both IbC and BB. Moreover, both effects were of equivalent magnitude. Thus, when no causal interpretation is suggested through instructions, BB and IbC seem to be empirically undistinguishable, at least when a standard BB and IbC design is used. It seems therefore sensible to suggest that in the absence of causal reasoning processes, compound training of cues do not seem to add anything to separate training of cues. This, in turn shows the difficulties of inferring BB when the appropriate control is used in situations in which participants do not engage in causal reasoning processes.

Of course, because no independent test was used to assess whether participants gave a causal interpretation to cues and outcomes, one could still think that participants could have engaged in causal reasoning processes. However, this possibility seems quite unlikely. Interpreting coloured rectangles as causing the presence of plants or the presence of plants as making rectangles take on different colours in the context of a gambling task would require something more than merely labelling cues and outcomes as cause or effect. Such interpretation has to be framed within the context of a causal scenario based on plausible causal laws and causal mechanisms. However, given that the instructions did not suggest any causal scenario at all, a good amount of cognitive load would have been necessary to come up with causal laws or causal mechanisms connecting cues and outcomes, not to mention the questionable benefit from doing this to face the learning task.

Accepting that causal inference processes are very unlikely to have been involved, we could explain our result in associative terms. The associative explanations of BB are based on the role played by within-compound associations. According to these explanations, BB should not be observed in the absence of within-compound associations (e.g., Dickinson & Burke, 1996). Although the BB effect obtained in our experiment is a straightforward prediction of these models, the IbC effect observed is clearly not predicted because the interfering cue presented during the second phase was never trained in compound during the first phase with the interfered cue. On the other hand, if we assume that participants encoded the AB, EF, and CD compounds as unitary configurations (not reducible to its elements, e.g., Pearce, 1994), the BB treatment would become X-O1, B-O1 (where X stands for the representation of the compound), and the IbC treatment would become Y-O3, G-O3 (where Y stands for the representation of the compound). Hence, these two training conditions would be equivalent IbC conditions and the mechanisms underlying IbC would cause a response decrement in both conditions.

It is important to note, however, that before speculating on a common interpretation of BB and IbC, we need to gather more compelling evidence regarding the relationship between both phenomena. This would certainly involve the use of dissociation strategies, which are more suitable to test whether the two phenomena are produced by the same processes or not. At the moment, our study is one step before in that it clearly shows the potential confounding between BB and IbC in non-causal learning tasks, leaving open the question of whether most of the BB results reported so far are true instances of BB or not. Hence, our study points to the need of controlling for IbC in BB experiments.

Thus, although there are numerous studies that have reported BB effects (e.g., Dickinson & Burke, 1996; Shanks, 1985; Van Hamme & Wasserman, 1994; Wasserman & Berglan, 1998), very few compared BB against IbC, and among those that did compare both effects (Escobar et al., 2002; Vadillo et al., 2008), none of them used a situation which makes causal reasoning processes unlikely. In some cases, although the experiments conducted have not been intended to explicitly compare BB with an IbC control, the design used can be easily regarded as well-suited for that purpose. For example, Larkin, Aitken, & Dickinson (1998) reported three experiments in which they failed to observe any evidence for BB when they used a control condition that was actually equivalent to our IbC condition. They used several overshadowing controls sharing the same outcome, e.g., GH-O1, IJ-O1, which could be considered as equivalent to our IbC condition (see Table 1). Thus, their results could be readily interpreted as showing, like the present ones, effects of BB and IbC which are empirically identical. The only case in which they reported a BB-like effect was when their control consisted of presentations of Cue B predicting the absence of the outcome during Phase 2 (i.e., a condition called recovery from overshadowing because it tends to enhance, rather than reduce, the response to the target cue).

In summary, the main contribution of the present study is the finding of empirically equivalent effects of BB and IbC when causal reasoning processes are unlikely to be involved. Further experiments should be conducted to find out whether these effects are empirically distinguishable in other experimental conditions.

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Figure Captions

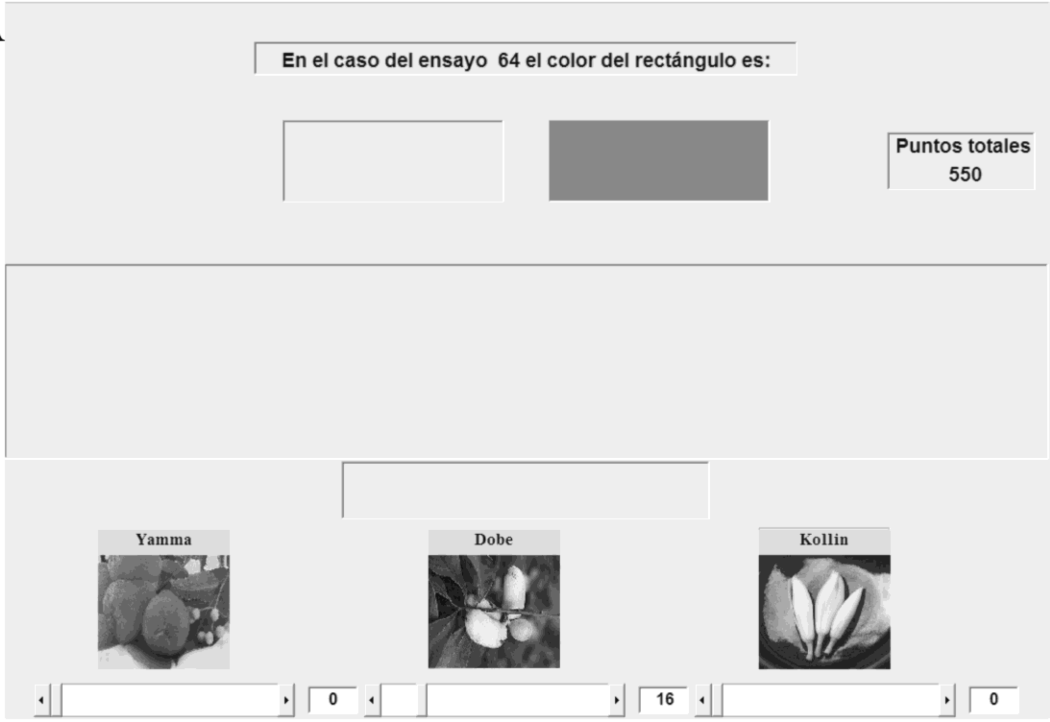
Figure 1. Information displayed on a training trial, as seen during the actual task. (A) Cues presentation. The cues were presented in the two rectangles at the top of the screen. The darker grey shaded rectangle represents a cue presented on the current trial, i.e., this figure represents a single cue trial. Participants could only respond during the 2.5 s. interval in which the rectangle stayed colored (i.e., cue present). The pictures of plants at the bottom of the screen represent the three possible response options. The scrollbars were used to bet points on each outcome (see main text). After this period of time, the outcome screen was automatically presented. (B) Outcome presentation. The photos of the incorrect plants and their names disappeared jointly with the cue or cues. Only the photo of the correct plant (the outcome) remained on the screen with its name and the number of points gained or lost. Participants had to press the ‘‘X” key to continue with the next trial.

Figure 2. Mean responses to cues A (Backward Blocking), C (Overshadowing control) and E (Interference between Cues). Error bars represent standard errors of the mean.

Table 1. Design summary of the Experiment

Phase 1 (20 trials)	Phase 2 (15 trials)	Test Phase (one ea)
AB→O1	B→O1	
CD→O2	-	A? C? E?
EF→O3	G→O3	

A


En el caso del ensayo 64 el color del rectángulo es:
Puntos totales
550
Yamma
Dobe
Kollin
0
16
0

B


En el caso del ensayo 64 el color del rectángulo es:
Puntos totales
566
Tu puntuación en este ensayo es:
16 puntos
Dobe
0
16
0

Figure # 1

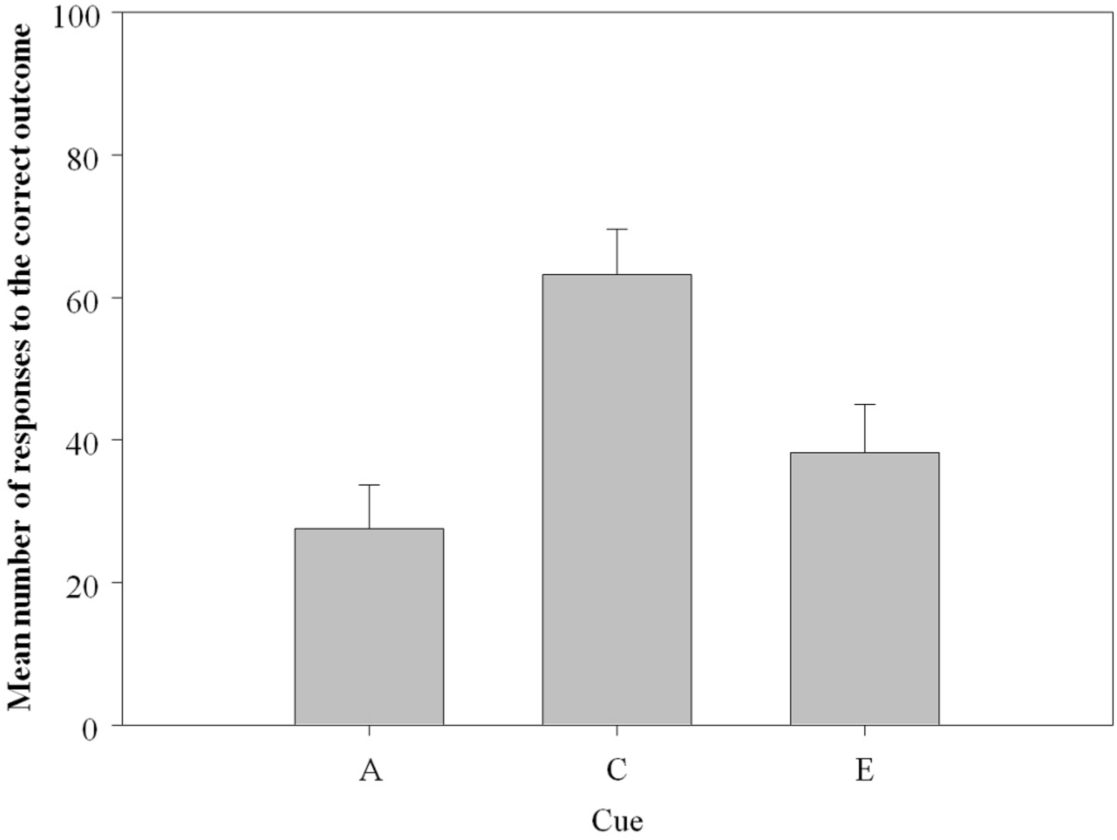

Mean number of responses to the correct outcome
100
80
60
40
20
0
A
C
E
Cue

Figure # 2

Appendix

Instructions (Translated from Spanish)

In the task that you are going to do next you will have to earn as many points as possible. To do so, please read the following instructions with great care and attention. The task is divided in a series of temporal intervals or trials. During these trials you will have to learn the relationships between some coloured rectangles and the pictures of three plants. In each trial you must learn which of the three plants is associated with the coloured rectangles that appear at the top of the screen. The three plants will be visible since the beginning of each trial. To add points to your score you must press the key that corresponds to the plant that you believe is related to the colour of the rectangles on top. If you press the key related with another plant, these points are going to be subtracted from your total score.

During the task, in each trial, you will find two rectangles at the top of the screen. They will be grey at the beginning of the trial, and could then become coloured (one or both of them), during a few seconds. During the seconds they are coloured, you must decide which plant is related with these colours. If you believe that it is the plant which is on the left, you must push the “1” key on the keyboard. If you believe that it is the plant which is on the center, you must push the “2” key on the keyboard. If you believe that it is the plant which is on the right, you must push the “3” key on the keyboard. The more you press the keys the more point you could win (or lose) in each trial. Moreover, the points that you can earn or lose could rise faster if you maintain the keys pressed down. It is important that you press the key corresponding to the plant related with the coloured rectangles at the top of the screen. If you make a mistake, the points that you bet in that trial will be subtracted from your total score. In each trial you can see the points you are betting for each plant in a lateral bar, as well as a counter next to each plant. After pressing (or not pressing) the keys “1”, “2” or “3” you will see the following information: (1) The number of points that you have won (or lost) in that trial. (2) The right plant (that is, the plant you should have bet more points on). You will know that this one is the right plant because it will be the only one visible in the screen right after you place your bet. The wrong plants will disappear so you can see which is the correct one. Therefore you will know if you are doing it right.

For your convenience, the total number of accumulated points can always be seen in the right top corner of the screen. To continue to another trial, press the X key.

It is important to keep in mind that the location of each plant in the screen may change from trial to trial. The colours are associated with the plant, not with its location. Thus, you have to memorize the “colour-plant” association in order to earn points, not the “colour-key” association (1, 2, or 3). The reason for that is that the plants changes their location, so, if you want to bet points for one plant you should press different keys in each trial.

In sum, if you want to earn points you should learn the “colour – plant” relationships and press the key corresponding to the correct position. The “1”, “2” and “3” keys can be pressed while the rectangles remain in colour (not grey).

IT IS VERY IMPORTANT that the index finger of your right hand remains over the “1” key, the middle finger of your right hand over the “2” key and the ring finger of your right hand over the “3” key during the whole experiment. If you do not do it like this, you will have to look for the keys each time you want to press them.

At the end of the experiment, in some of the latest trials, you will not have access to the information about which plant was the correct one after you place your bet. After a test trial like this one, just continue performing the task normally.

REMEMBER: Your mission is to learn the relationship between the rectangles of different colours and the plants in order to earn the maximum possible number of points.

If you have any doubt, please, ask us!