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Contingency is used to prepare for outcomes: Implications for a functional analysis of learning

Fernando Blanco, Helena Matute, and Miguel A. Vadillo
Deusto University, Bilbao, Spain

It is generally assumed that the function of contingency learning is to predict the occurrence of important events in order to prepare for them. This assumption, however, has scarcely been tested. Moreover, the little evidence that is available suggests just the opposite result. People do not use contingency to prepare for outcomes, nor to predict their occurrence, although they do use it to infer the causal and predictive value of cues. By using both judgmental and behavioral data, we designed the present experiments as a further test for this assumption. The results show that—at least under certain conditions—people do use contingency to prepare for outcomes, even though they would still not use it to predict their occurrence. The functional and adaptive aspects of these results are discussed in the present article.

It is generally assumed that in order to survive, people and animals need to extract contingency information from the environment. Doing this allows them to infer causal relations and to predict when important events will occur, which in turn allows them to prepare for these outcomes (see, e.g., Dickinson, 1980; Hollis, 1997). The large number of experiments on contingency learning that have been published during the last decades (see Shanks, 2007, for a recent review) are justified precisely on these premises. Contingency learning is critical for survival because it ultimately allows organisms to prepare for important events. A functional analysis of contingency learning, therefore, calls for the investigation of preparatory behavior. Thus, the scant attention that preparatory judgments have captured in the research community is highly surprising. Preparatory judgments are not just one more additional type of judgment. They are the judgments that most naturally show the function that has traditionally been attributed to contingency learning. Indeed, if preparing for outcomes provides the function of contingency learning, then one would expect preparatory behavior to be closely dependent on contingency information. Quite surprisingly, the (little) data available on preparatory judgments suggest otherwise.

The most commonly used metric of contingency is ΔP, which is the difference between the probability of the outcome when the cue is present, $p(O|C)$, and the probability of the outcome when the cue is absent, $p(O|\neg C)$ (Jenkins & Ward, 1965). The experimenter can manipulate the strength of the cue–outcome contingency by varying the frequencies with which the cue (e.g., a fictitious medicine) and the outcome (e.g., a fictitious allergic reaction) occur or do not occur together. Interestingly, some reports have suggested that these contingency manipulations have a different effect on causal judgments than on predictive and preparatory judgments. For example, Vadillo, Miller, and Matute, (2005; see also Vadillo & Matute, 2007) showed that contingency information had no impact on participants' likelihood of predicting the outcome in the presence of the cue. At the same time, however, participants in those studies showed an accurate use of contingency information to estimate both the causal and the predictive value of the cue. Thus, apparently, people use contingency to infer causal and predictive value, even though they do not use it to predict the likelihood that the outcome will follow.

In a related study, De Houwer, Vandorpe, and Beckers (2007) showed that contingency information was used to make accurate estimates of causal relations, whereas it had little impact on participants' stating that they would prepare for the outcome when the cue was present. Consistent with the findings of Vadillo et al. (2005) regarding outcome predictions, $p(O|C)$ seemed to be the main determinant of preparatory judgments as well.

At least at first glance, those results seem quite contrary to the idea that opened the present article—that contingency knowledge is needed both to predict the occurrence of important events and to prepare for them. From a normative point of view, it certainly does make sense to neglect the value of contingency when making predictions. After all, the value of $p(O|C)$ is the only thing one needs to know when predicting whether the outcome will follow the cue. Information on $p(O|\neg C)$ becomes absolutely irrelevant in this case. But the potential dissociation between contingency and preparatory behavior is not that obvious. On the one hand, preparatory judgments, like predictions, could simply rely on $p(O|C)$. People could prepare for the outcome whenever

H. Matute, matute@fice.deusto.es

they know it will occur. On the other hand, however, it is not clear that the most adaptive behavior that one can adopt when preparing for an outcome should rely simply on $p(O|C)$. If the outcome is occurring with the same probability regardless of whether the target cue is present or absent, this becomes a situation in which the outcome follows the cue regularly, but without any predictive relation between them. The cue is not a signal for the outcome, but a completely unrelated event. In this situation, organisms should look for another cue with greater predictive value to help them decide when to act, or else they will have to be preparing at all times for any of the many possible outcomes that could follow any of the millions of cues that are present at any given time. There are so many potential outcomes for which there are no known causes (or good signals) that it becomes impossible to prepare for them all. Thus, when preparing for outcomes, it might be much more efficient to rely on the predictive value of the cue, which depends on contingency, rather than on $p(O|C)$. Indeed, if any conclusion can be drawn from decades of related research on Pavlovian conditioning, it is that nonhuman animals do use contingency to prepare for outcomes (Rescorla, 1968). As for human preparatory Pavlovian responses, we know of no study that has tested whether they rely on cue–outcome contingency rather than on $p(O|C)$.

In sum, further evidence is needed before we can reject (or accept) the general assumption that people use contingency information to prepare for outcomes. Although several studies have shown a dissociation between causal judgments and predictions (e.g., Gredebäck, Winman, & Juslin, 2000; Matute, Vegas, & De Marez, 2002; Vadillo et al., 2005; Vadillo & Matute, 2007), the evidence of the dissociation between contingency and preparatory judgments relies on only one study (De Houwer et al., 2007). Moreover, none of the aforementioned studies has explored the effects of contingency information on both outcome predictions and preparatory judgments. If our hypothesis is correct, then preparatory judgments, not predictions, might show sensitivity to contingency.

EXPERIMENT 1

Method

Participants. Fifty-one college students voluntarily took part in the study. A random assignment of participants into two groups resulted in 24 participants in Group High, and 27 in Group Low.

Procedure and Design. Participants were told to imagine that they were physicians who were trying to find out whether a relationship existed between a cue (a fictitious medicine, *Dugetil*) and an outcome (a side effect—skin rash—in a fictitious patient).

$p(O|C)$ was 1 in both groups, but $p(O|\neg C)$ was .5 in Group High and 1 in Group Low. Therefore, Δp was .5 in Group High and 0 in Group Low. This should permit us to compare the sensitivity of causal, prediction, and preparation judgments to specific manipulations of covariational information. Judgments that are only sensitive to $p(O|C)$ should not differ between these two groups, but judgments that are sensitive to Δp should.

Participants received 120 medical cards, 1 per trial. In cue-present trials, the computer screen showed the phrase *Mr. X has taken Dugetil* and a picture of a pill bottle. In cue-absent trials, the phrase *Mr. X has not taken Dugetil* and a picture of a bottle crossed in red were shown. To encourage their attention, participants had to answer the question *Do you think that Mr. X is going to develop a skin rash?* by clicking the "yes" or "no" button in every trial. Then, a feedback panel showed either the phrase *Mr. X has developed the skin rash* and a picture of an ill face (outcome-present trials), or the phrase *Mr. X has not developed the skin rash* and a picture of a healthy face (outcome-absent trials).

At test, every participant emitted three different judgments: a causal judgment (*To what extent do you think that Dugetil is the cause of the skin rash that Mr. X suffers?*), a prediction judgment (*If Mr. X has taken Dugetil, to what extent do you think that he will develop a skin rash?*), and a preparation judgment (*If Mr. X has taken Dugetil, to what extent would you recommend him to take an ointment in order to prevent a skin rash?*). The three questions were displayed simultaneously, with their position (upper, middle, or lower panel of the screen) counterbalanced between participants. A rating scale ranging from 0 (labeled *Definitely NOT*) to 100 (labeled *Definitely YES*) was displayed below each question.

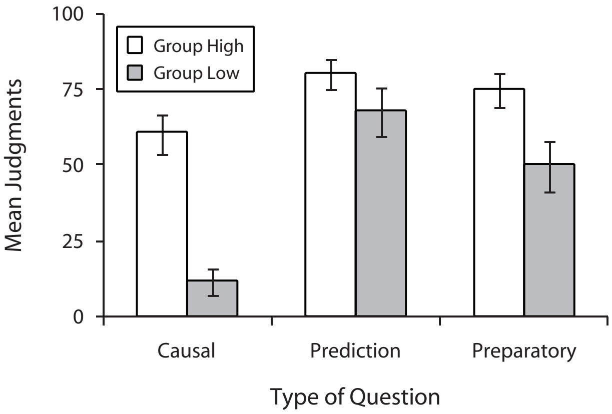

Figure 1. Mean judgments in Experiment 1. Error bars represent 1 standard error of the mean.

Results

Figure 1 depicts the mean judgments at test. As was expected, a 3 (question) × 2 (contingency) ANOVA showed significant main effects of question [$F(2,98) = 27.10$, $p < .001$] and contingency [$F(1,49) = 17.07$, $p < .001$], as well as an interaction [$F(2,98) = 6.14$, $p < .01$]. Both causal and preparatory judgments were significantly higher in Group High than in Group Low [$t(49) = 6.46$, $p < .001$, and $t(49) = 2.41$, $p < 0.05$, respectively]. This indicates that both of these judgments were affected by contingency. Prediction judgments did not significantly differ as a function of contingency [$t(49) = 1.28$, $p = .21$].

EXPERIMENT 2

As was expected, in Experiment 1 we showed that both causal and preparatory judgments, but not predictions, were affected by contingency information. The results of the causal and prediction judgments were consistent with those of several previous human studies (e.g., Gredebäck et al., 2000; Matute et al., 2002; Vadillo et al., 2005; Vadillo & Matute, 2007). However, the results on preparatory judgments, although expected, contradicted the null result reported by De Houwer et al. (2007). Our Experiment 2, therefore, had several goals. The first one was to provide a replication for the results of Experiment 1 using a very different procedure, in which most parameters changed, allowing the generality of the effect to be assessed. The most important change in this experiment was probably that in our dependent variable. A functional analysis of contingency learning cannot rely solely on what people say that they would do (i.e., their subjective, verbalized judgments), or what they say that somebody else should do. Our analysis needed convergent evidence from the actual, nonverbal, preparatory behavior. Experiment 2 was aimed at extending the findings of Experiment 1 to a more comprehensive framework that included not only verbal (numerical) judgments but also, most importantly, the nonverbal preparatory behavior itself. On a lesser point, we also aimed at using less extreme contingencies. Although extreme values were needed for a fair comparison with previous research [i.e., both De Houwer et al., 2007, and Vadillo et al., 2005, used a contingency of 0 and a $p(O|C)$ of 1], and although the difference between the contingency and $p(O|C)$ needed to be large for the dissociation to be observed, we thought it was important to use a lower $p(O|C)$ so as to make sure that the results were not restricted to the special condition in which the outcome is always present. Also, in order to make sure that the dissociation observed in the judgmental responses in Experiment 1 was not the result of our presenting all of the questions in the same screen, we manipulated the question type between participants, with each participant answering only one question. Finally, we used predictive-value rather than causal-value questions. If our hypothesis was correct, the dissociation that we observed between prediction and causal-value judgments should also have been observed between prediction and predictive-value judgments (see, e.g., Vadillo et al., 2005).

Method

Participants. Thirty-four anonymous volunteers took part in the study. A random assignment resulted in 16 participants in the high-contingency condition, and 18 in the low-contingency condition. Orthogonally, 16 participants emitted a prediction judgment at the end of training, and 18 emitted a prediction-value judgment.

Procedure and Design. In Experiment 2, we used the Martians video game that was originally developed by Arcediano, Ortega, and Matute (1996); however, we used the new and improved version that was developed by Franssen, Clarysse, Beckers, van Vooren, and Baeyens (in press),[1] and we also incorporated several interesting features that were developed by Costa (2009; see note 1). In the Martians paradigm, the suppression of barpressing behavior is used as an analogue to animal conditioning suppression to assess preparatory behavior in humans. The participants' goal is to prevent Martians from landing on Earth. Martian spaceships appear on the computer screen at a rate of one spaceship every 250 msec. Participants are told to fire their laser guns by pressing the space bar, and to destroy as many spaceships as possible. Doing this results in a stable barpressing rate. From time to time, the Martians activate an antilaser shield consisting of screen flashes and a distinctive sound with a duration of 500 msec. This shield is the outcome to be prepared for. If the participant continues pressing the bar when the shield is active, the laser gun becomes deactivated for 5 sec, and dozens of spaceships invade the screen faster than usual (one spaceship every 50 msec). These invasions cannot be escaped once started. Thus, to avoid them, participants have to suppress their barpressing behavior immediately before the shield is connected. Participants are also told that there will be some cues that sometimes may (or may not) be followed by the activation of the shield. If participants learn that a cue is a good predictor of the shield, then they should respond to this cue by suppressing their barpressing behavior in anticipation of the outcome. Suppression ratios are conventionally assessed as $A/(A + B)$, where A is the number of barpresses during the cue and B the number of barpresses in a period of time identical to the duration of the cue and immediately preceding it.

In Experiment 2, the training phase consisted of 69 trials in pseudorandom order. In both groups, the target cue was presented in 30 trials, and the activation of the shield followed 80% of them (24 trials). Contingency was manipulated by varying the percentage of trials in which the context, rather than the cue, was followed by the outcome. In the high-contingency condition, the context was never followed by the activation of the shield, whereas in the low-contingency condition, the context was followed by the shield 80% of the time (i.e., 24 trials), thereby making the target cue noncontingent on the shields despite its high probability of being reinforced. An additional 15 trials were used in both groups with a filler cue that was never followed by the shield, and its only purpose was to prevent indiscriminate suppression (Arcediano et al., 1996). The target and filler cues were two "Martian letters," counterbalanced, that represented the interception of messages between spaceships (Costa, 2009). They appeared from time to time for a duration of 1.5 sec. At test, the target cue was presented for 3 sec so that the suppression ratio could be assessed (see Arcediano et al., 1996). Intertrial intervals lasted between 7 and 13.50 sec.

Upon completion of the Martians task, the judgmental variables were assessed between participants. The screen presented the target cue and a question that had to be answered with a number between 0 and 100. Half of the participants in each contingency condition received a prediction question: *If this cue* [image of target cue inserted here] *appears on the screen, to what extent do you think that the shield will be activated?* The other half received a predictive-value question: *To what extent do you think that the onset of this cue is a good predictor of the activation of the shield?*

Results

Behavioral data. The results of Experiment 2 were as expected. Participants in the high-contingency condition suppressed their barpressing behavior more in response to the target cue ($M = .20$; $SEM = .11$) than did those in the low-contingency condition ($M = .27$; $SEM = .23$) [$F(1,32) = 7.08$, $p < .05$]. (Recall that values closer to 0 indicate stronger suppression—that is, stronger preparatory behavior in response to the target cue.) Thus, participants' preparatory behavior was significantly affected by the contingency between the cue and the shield, with those exposed to a higher contingency being the ones who suppressed their behavior the most.

Judgments. Figure 2 plots the mean judgments by group in this experiment. A 2 (contingency) × 2 (question) ANOVA yielded a significant interaction [$F(1,30) = 6.46$, $p < .05$]. No main effects for contingency [$F(1,30) = 2.40$, $p = .132$] or for question [$F(1,30) = 2.20$, $p = .148$] were found. Consistent with our hypothesis and with previous literature, predictive-value judgments were significantly affected by the contingency manipulation [$F(1,16) = 10.51$, $p < .01$], whereas prediction judgments were not [$F(1,14) = 3.97$, $p = .54$].

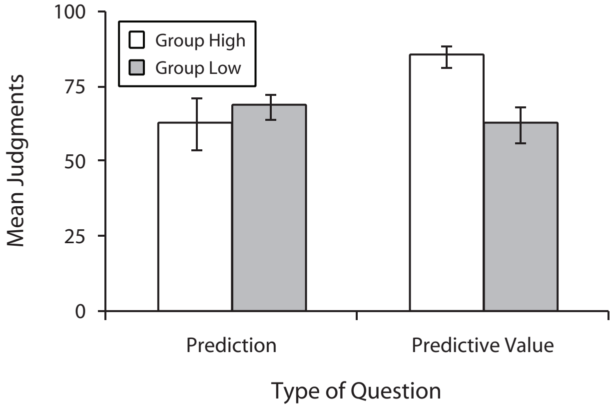

Figure 2. Mean judgments in Experiment 2. Error bars represent 1 standard error of the mean.

DISCUSSION

As was noted in the introduction, it is often assumed that the reason why humans and animals extract contingency information from the environment is a very practical one: being able to identify those cues that signal important events, so as to be able to predict their occurrence and prepare for them.

Previous research has indeed shown that animals use contingency information to prepare for outcomes (Rescorla, 1968). It has also shown that people use contingency information to acquire knowledge not only about causation, but also about the predictive (signal) value of the cues in the environment (Vadillo et al., 2005; Vadillo & Matute, 2007). However, it has also shown that people do not use this knowledge to predict the outcomes (see, e.g., Gredebäck et al., 2000; Matute et al., 2002; Vadillo et al., 2005; Vadillo & Matute, 2007) or to prepare for them (De Houwer et al., 2007). This seems inconsistent with the general assumption that the function of contingency learning is to predict and prepare for outcomes.

Our present experiments have shown that preparatory judgment and behavior are sensitive to contingency. The two experiments used very different procedures and dependent variables and demonstrated consistently that preparatory judgments and behavior were significantly stronger when there was a high level of contingency. Participants also used contingency to detect which cues had the higher causal and predictive values. Consistent with previous reports, however, outcome predictions were not based on contingency (see, e.g., Gredebäck et al., 2000; Matute et al., 2002; Vadillo et al., 2005; Vadillo & Matute, 2007). Similar dissociations have been found for judgments about the frequency with which the outcome follows the cue (Matute, Arcediano, & Miller, 1996) and for outcome recall in the presence of the cue (Mitchell, Lovibond, & Gan, 2005). Both of them also appear to be independent of contingency and different from causal judgments. Moreover, related research is also showing that people tend to use base rates, rather than contingencies, to infer correlations and to make predictions (Fiedler, Freytag, & Meiser, 2009).

We cannot know the reason why De Houwer et al. (2007) observed a null result in the sensitivity of preparatory judgments to contingency, but the main differences between our judgmental study (Experiment 1) and theirs are that we manipulated contingency between, rather than within, participants; we used 120 training trials rather than 10; and we assessed preparatory responses differently. These, and perhaps several other differences we are not aware of, increased the chances that the sensitivity of preparatory judgments to contingency could be detected in our studies.

Why, then, is contingency learning used to prepare for outcomes if it is not used when predicting their occurrence? If the outcome is occurring often, regardless of whether the cue is present or absent, a normatively adjusted response should be sensitive to several facts: (1) The contingency between the cue and the outcome is 0; (2) the causal value of the cue is 0; (3) the predictive value of the cue is 0; (4) the probability that the outcome will occur in the next trial is high; and (5) the likelihood (the prediction) that the outcome will occur following the cue is high. However, which would be the most effective preparatory behavior? A preparatory response speaks to the question of what should be the best possible use of knowledge and information in order to best adapt to the demands of the environment. This includes making good use of knowledge and information, but also of energy resources and cost-efficient behavior. Therefore, this also includes assessing the high cost of emitting a preparatory response in all trials, irrespective of the predictive value of the cue. What the present experiments have shown is that once participants know that the outcome will occur with a given probability and that there are no clues as to what its cause can be, they learn that it makes no sense to keep preparing for that outcome whenever any of the many irrelevant cues in the environment are present (or at least it makes no sense to prepare as intensely as if it were contingent). Although we are often able to predict the occurrence of important events just by looking at their base rates, it would be impossible to prepare for all types of outcomes that may occur, irrespective of their degree of contingency with the signals that are present.

Because predictions, preparatory behavior, and prediction-value judgments are so often taken as synonyms, we all tend to assume that animals use contingency to predict the outcomes. However, the only thing we can know for sure when we work with animals is that they use contingency to prepare for outcomes. Whether they use contingency because they predict the outcome or because they know that the cue has a high predictive value is something that, to our knowledge, has not been addressed in the animal literature. Our results suggest that, in addition to preparation behavior, it is the predictive value of cues rather than the predictions of the outcome that requires contingency. This point should be valid for human and nonhuman animals.

In sum, the present experiments have shown that contingency learning may have survival value after all. It is true that we do not need it to know the likelihood that an outcome will occur, but we do need it if we want to be able to select those signals with the higher predictive (or causal) value in our environment so that we can engage in efficient preparatory behavior. Most importantly, and regardless of the merits of the particular account we have presented herein, our research calls for the need to add preparatory judgments and behavior to the research agenda of contingency learning. As was noted in the introduction, the little attention that preparatory judgments and behavior have captured in the human learning research tradition is surprising, and it will be a task for future research to investigate under which conditions contingency learning is or is not useful for preparing for outcomes.

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NOTE

1. We thank these researchers for sending us their improved versions of the program. Special thanks are due to M. Franssen for helping us program the experiment using the Leuven version.

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