Outcome and cue properties modulate blocking

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Participants saw a series of situations in which a cue (a light appearing at a certain position) could be followed by an outcome (a drawing of a tank that exploded) and were afterwards asked to rate the likelihood of the outcome in the presence of the cue. In Experiments 1 and 2, the compound cues AT and KL were always followed by the outcome (AT+, KL+). During an elemental phase that either preceded or followed the compound phase, Cue A was also paired with the outcome (A+). Cue T elicited a lower rating than Cues K and L when cues were described as being weapons but not when the cues were said to be indicators. The magnitude of this blocking effect was also influenced by whether the outcome occurred to a maximal or submaximal extent. Experiment 3 replicated the effect of cue instructions on blocking (A+, AT+) but showed that cue instructions had no impact on reduced overshadowing (B−, BT+). The results shed new light on previous findings and support probabilistic contrast models of human contingency judgements.

In human contingency judgement experiments, participants are exposed to a number of situations in which cues and outcomes are either present or absent. On the basis of what they observe during these situations, participants are asked to make judgements about the relation between the presence or absence of a cue and an outcome. The results of several studies (e.g., Dickinson, Shanks, & Evenden, 1984; Shanks, 1985) have shown that when a cue T is always presented together with an alternative cue A and both are followed by the outcome, O (i.e., AT+ trials), judgements about the contingency between T and O are lowered when Cue A on its own was previously paired with the outcome (i.e., A+ trials). This result, referred to as blocking, led to the development of a number of theories of human contingency learning.

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According to the probabilistic contrast model (Cheng & Holyoak, 1995; Cheng & Novick, 1990; Waldmann & Holyoak, 1992), participants make contingency judgements by calculating whether and to what extent the probability of the outcome depends on the presence or absence of the cue. In doing so, they will try to select a focal set of situations in which the presence or absence of competing cues is constant.

\[ V_c = p(O/A.T) - p(O/A.\sim T) \]

For instance, when applying Equation 1, only situations in which Cue A is present are taken into account, and it is determined whether the presence or absence of Cue T influences the probability of the outcome O in these situations. According to the probabilistic contrast model, Cue T receives a low rating when AT+ trials are preceded by A+ trials because the probability of the outcome in the presence of A and T, \( p(O/A.T) = 1 \), is the same as the probability of the outcome when only A is present and T is absent, \( p(O/A.\sim T) = 1 \).

Blocking can also be explained by associative models that were originally developed to account for findings obtained in studies on Pavlovian conditioning in animals. One such associative model that has explicitly been put forward as a model of human contingency judgements is the Rescorla–Wagner model (Rescorla & Wagner, 1972). According to this model, human contingency judgements are a reflection of the acquired strength of the association between two stimuli. The strength of the association between a target cue T and an outcome O is updated according to Equation 2 on each trial where the cue is present.

\[ \Delta V_n = \alpha \beta (l - \Sigma V_{n-1}) \]

The magnitude of the change in associative strength on trial \( n \) (\( \Delta V_n \)) depends on the difference between \( l \) and the sum of the existing associative strength of all cues that are present on trial \( n \) (\( \Sigma V_{n-1} \)). When the outcome is present, \( l \) is set at a fixed positive value (e.g., \( l = 1 \)); when the outcome is absent, \( l \) is set at 0. Therefore, when the existing associative strength of a Cue T is low, and when no other cues are present or the other cues that are present have a low associative strength, the crucial difference will be positive and large, leading to a strong increase in associative strength of the Cue T. If, however, Cue T already has a high associative strength on trial \( n - 1 \) or when it has a low associative strength but is accompanied by other cues with a high associative strength, the difference will be small and thus the associative strength of Cue T changes very little. Therefore, the Rescorla–Wagner model predicts blocking effects because changes in the associative strength of Cue T depend on the associative strength of other cues that are presented together with Cue T.

However, the Rescorla–Wagner model is incompatible with the observation that blocking effects also occur when the A+ trials are presented after the AT+ trials (e.g., Larkin, Aitken, & Dickinson, 1998; Shanks, 1985; Williams, Sagness, & McPhee, 1994). This result is known as backward blocking. According to the Rescorla–Wagner model, A has no associative strength prior to the AT+ trials, and thus T is not prevented from gaining associative strength. The probabilistic contrast model, on the other hand, predicts both forward and backward blocking: Whether the A+ trials are presented before (as is the case in forward blocking) or after (as is the case in backward blocking) the AT+ trials should not matter according to the probabilistic contrast model because the order of events does not influence the probabilities as calculated in Equation 1. Although backward blocking thus promised to differentiate between the
probabilistic contrast model and the Rescorla–Wagner model, some have noted that a slight modification of the Rescorla–Wagner model does allow it to account for backward blocking (Dickinson & Burke, 1996; Van Hamme & Wasserman, 1994). Moreover, such a revised Rescorla–Wagner model is compatible with the observation that backward blocking appears to be smaller in magnitude than forward blocking (e.g., Williams et al., 1994), a finding that is at odds with the probabilistic contrast model.

From this, it should be clear that blocking is a theoretically important phenomenon. The aim of the present experiments was to further explore the conditions under which blocking effects can be observed. More specifically, we looked at whether properties of the outcomes and the cues could influence the magnitude of forward and backward blocking effects.

On the basis of recent formulations of the probabilistic contrast model (Cheng, 1997; Cheng & Holyoak, 1995), one can predict that blocking will in some cases depend on whether the outcome is a discrete event (either present or absent) or a continuous event (occurring with a certain intensity). As was mentioned earlier, the probabilistic contrast model postulates that participants judge the relation between a target Cue T and an outcome O on the basis of the outcome of probabilistic contrasts in which the presence of alternative cues is kept constant. However, Cheng (Cheng, 1997; Cheng & Holyoak, 1995) pointed out that from a logical point of view, the outcome of such a contrast does not provide an accurate basis for contingency judgements when the outcome is a discrete event that always occurs both in the presence and in the absence of the target cue, \( p(O/A.T) = p(O/A.\sim T) = 1 \). Cheng (1997) illustrates this point with the following example: Assume that a physician wants to test whether a person is allergic to a certain substance T. (S)he therefore puts scratches on the patient’s arm, some that contain the substance, others that do not. Surprisingly, hives break out at each spot, regardless of whether the scratch contained the substance, \( p(O/A.T) = p(O/A.\sim T) = 1 \). If we regard scratching the skin as an alternative cue A, the probabilistic contrast for T equals zero, \( p(O/A . T) - p(O/A . \sim T) = 0 \), which should thus result in a low contingency judgement for T. However, it is also possible that T does cause an allergic reaction but that the effect of T is not observable because the alternative cause (i.e., scratching) on its own always causes an allergic reaction.

Cheng and Holyoak (1995) argued that participants are aware of this limitation in the interpretation of probabilistic contrasts and that they will not rely on the outcome of an appropriate probabilistic contrast when the outcome is a discrete event that always occurs. Moreover, because T is always presented together with A, participants cannot determine the alternative, more informative contrast that reflects contingency between T and the outcome in the absence of A—that is, \( p(O/\sim A.T) - p(O/\sim A.\sim T) \). Therefore, participants will be unsure of the relation between the target cue and the outcome. Whereas Cheng and Holyoak had to extend the probabilistic contrast model with the auxiliary process assumption that participants take into account the limitations of a probabilistic approach, Cheng (1997) provided a theoretical reformulation of the probabilistic contrast model that in itself specifies the boundary conditions. Cheng (p. 372) argued that people believe “that there are such things in the world as causes that have the power to produce an effect” and that each cause is assumed to have a certain causal power. In the Power PC model that she proposed, causal power (\( P \)) is estimated by comparing the appropriate probabilistic contrast with the base rate of the outcome. In a blocking situation, causal power can be estimated as in Equation 3.
When the outcome is a discrete event that is always present in the absence of T, \( p(O/A.\sim T) = 1 \), the equation is undefined and participants should be uncertain about the relation between T and O rather than certain that T and O are unrelated. As such, an important boundary condition of probabilistic contrasts is incorporated in the model itself.

Cheng (1997, p. 384) noted, however, that when the outcome is a continuous event that occurs with a certain, submaximal intensity, participants can make inferences about the causal power of a cue even when the outcome always occurs on A and AT trials\(^1\). Again take the example of the allergy test. Assume that hives vary in intensity. If hives always occur at a maximal intensity on both A and AT trials, the situation is analogous to the situation in which the presence of hives is considered to be a discrete event that always occurs on the A and AT trials. However, if scratching alone leads to hives that are less intense than the maximal intensity (A\(^+\)), and scratching together with a substance leads to hives with the same intensity (AT\(^+\)), it is clear that the substance does not cause an increase in the allergic reaction that is produced by scratching on its own. Because multiple causes of the same outcome are assumed to have a combined effect on the intensity of the outcome (Cheng, 1997; Waldmann, 2000), one can infer with some degree of confidence that the substance does not lead to an allergic reaction. In the present experiments, we presented outcomes that either always occurred at a maximal extent on A\(^+\) and AT\(^+\) trials or always occurred at a submaximal extent on these trials. On the basis of the arguments put forward by Cheng (Cheng, 1997; Cheng & Holyoak, 1995; also see Waldmann, 2000), we predicted that blocking would be more pronounced with submaximal outcomes than with maximal outcomes. Note that the crucial manipulation relates to the information that participants receive about the maximal intensity of the outcome that can be measured, rather than to the information about the intensity of the outcome itself on A and AT trials. When continuous events do not have a specified maximal value, Cheng would predict that blocking should always occur because participants should always be able to verify whether T adds to the effect of A. However, by imposing a maximal intensity of the outcome that either corresponds to the intensity of the outcome in the presence of A and AT (maximal outcomes) or is higher than the intensity of the outcome on A and AT trials (submaximal outcomes), one can effectively manipulate whether participants have the opportunity to verify whether T adds to the effect of A and thus whether T is a cause of the outcome.

We also examined whether the nature of the cues might have an impact on blocking. In studies that examined blocking in human contingency learning, cues have been described in two different ways. In some studies, participants were told that the cues were potential causes of the outcome. For instance, cues were said to be foods or medicines that caused allergies (e.g., Dickinson & Burke, 1996; Larkin et al., 1998; Van Hamme & Wasserman, 1994) or weapons that caused the destruction of tanks (e.g., Dickinson et al., 1984; Shanks, 1985). In other studies, however, cues were described as being indicators that did not cause the outcome but could be used to predict the occurrence of the outcome. For instance, cues could be individual stocks that predicted movements in the total value of the stock market (e.g., Chapman &

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\(^1\)It should be noted, however, the Power PC model as introduced by Cheng (1997) only deals with discrete outcomes. Cheng did not specify a formal model for situations in which outcomes are continuous events, and it is thus unclear how such a model would incorporate the assumption that ceiling effects do not occur with such outcomes.
Robbins, 1990) or various complex visual patterns that predicted the onset of one particular weapon (e.g., Arcediano, Matute, & Miller, 1997). Some findings suggest that the way in which the cues are described can have an important impact on the magnitude of blocking. For instance, Waldmann (2000; Waldmann & Holyoak, 1992; but see Shanks & Lopez, 1996) did not find blocking in common-cause situations in which cues were described as effects (e.g., symptoms) and outcomes as causes of these effects (e.g., diseases) but did find blocking when cues were introduced as multiple potential causes (e.g., diseases) of the outcomes (e.g., symptoms). In the present experiments, we tested whether the magnitude of blocking effects depends on whether cues are described as potential causes of the outcome or as indicators that merely predict the outcome.

We manipulated both the nature of the outcome and the nature of the cues within the same experiment because there are reasons to assume that the effects of both variables might interact. Effective causes should influence intensity of their outcome (Cheng, 1997). Therefore, when participants can verify that the presence of a target cause does not increase the intensity of the outcome (e.g., when the outcome occurs to the same submaximal extent on both A+ and AT+ trials), they can infer that the target is not a cause of the outcome. If participants cannot verify whether the target cause affects the intensity of the outcome (e.g., because the outcome always occurs to a maximal extent), they cannot make a reliable inference about the causal status of the target cue. On the other hand, the indicators in the present experiments are merely potential predictors of an outcome, just like lights on a railway crossing can predict the arrival of a train rather than causing the train to appear. Because the indicators do not have a causal effect on the outcome, it should be irrelevant whether participants can verify that the intensity of the outcome is the same with one indicator as with two indicators. In conclusion, we predicted that the nature of the outcome (maximal or submaximal) would only have an effect on blocking when targets are described as potential causes but not when targets are potential indicators.

In our experiments, we used a task that was similar to the task developed by Dickinson et al. (1984). Participants saw a series of trials on which the drawing of an army tank moved across a computer screen. On some of the trials, the tank exploded at a fixed position. Just before the tank reached the crucial position on the screen, a light could appear in certain positions at the bottom of the screen. Each possible position was indicated by a square. On a given trial, a light could appear in none or one of the squares, or simultaneously in two squares. Conceptually, each square can be regarded as a separate cue and the explosion of the tank can be regarded as the outcome. After observing a certain number of trials, participants were asked to make a judgement about the relationship between the presence of each of the cues (i.e., a light appearing in certain square) and the presence of the outcome (i.e., the tank exploding). In Experiments 1 and 2, blocking was examined as follows. During one phase, Cues A and T were always presented together, and the control Cues K and L were always presented together and were always followed by the outcome (AT+, KL+). This compound phase was either preceded (in the case of forward blocking, Experiment 1) or followed (in the case of backward blocking; Experiment 2) by an elemental phase in which A on its own was always followed by the outcome (A+). If the target Cue T receives a lower rating than the control Cues K and L despite the fact that T, K, and L only differ with regard to the fact that T but not K and L was presented in compound with a cue that was previously paired with the outcome (i.e., Cue A), this would provide a clear demonstration of a blocking effect.
The nature of the cues was manipulated in the following way. Half of the participants were told that the cues represented weapons that fired at the tank and were instructed to determine for each weapon separately how likely it was that a tank would be destroyed if that weapon fired. The other participants were told that the cues represented indicators that could be used to predict tank destruction. Their task was to determine for each indicator separately how likely it was that a tank would be destroyed when the indicator lit up.

We also manipulated the nature of the outcome by varying the information that participants received about the strength of the explosion of the tank. Participants who were told that the cues represented weapons were further informed about the fact that each time one or two weapons fired, they would receive information about the combined impact of the weapons on the tank. However, there was a limit to the impact that could be measured. Half of the participants in the weapons condition were told that this maximum corresponded to an impact score of 10, the other participants in the weapons condition were told that the maximum impact that could be measured corresponded to a score of 20. Importantly, for all participants, the impact score was 10 on each trial where the tank exploded and 0 on each trial where the tank did not explode. When the maximum impact score was 10, the outcome always occurred to the full extent on both A and AT trials. Under these conditions, participants should be uncertain about the causal status of the target Cue T. However, if the maximum impact score was 20, the outcome did not occur to the full extent on A and AT trials: Whether Weapon T fired together with Weapon A or Weapon A fired alone, the impact of the weapons was always 10 out of 20. This should allow participants to infer that Weapon T did not have an effect and therefore should increase the blocking effect.

The impact scores were also presented in the indicator condition. Participants in this condition were told that the impact score just provided additional information about the status of the tank. Half of the participants in the indicator group were told that the explosion of a tank would always be accompanied by the message “IMPACT 10/10”, and when the tank did not explode, the message “IMPACT 0/10” would be displayed. The other members of the indicator group saw the message “IMPACT 10/20” after tank destruction and “IMPACT 0/20” when the tank did not explode. However, for the reasons explained earlier, we did not expect the manipulation of impact scores to have an effect.

EXPERIMENTS 1 AND 2

The design of the experiments was as follows. We manipulated two between-subjects variables. The variable cue instructions determined whether the cues were described as weapons 2

2In a sense, the cues (i.e., lights at certain positions) are also indicators in the weapon condition. That is, the cues are not the weapons themselves but merely indicators that reflect when a particular weapon is firing. However, unlike what is the case in the indicator conditions, there is a clear one-to-one link between each cue and each weapon. Therefore, each cue can be said to represent a potential hidden cause in a common-cause situation (also see Waldmann, 2000, Experiment 1). Such a clear causal structure is not provided in the indicator condition. In that condition, nothing is said about the actual cause of the outcome (i.e., tank destruction) or about how the indicators are linked to the actual cause of the outcome. Participants are merely told that the cues are indicators that can help them predict an outcome. It is therefore likely that the participants do treat the indicators as merely potential predictors of the outcome (similar to lights at a railway crossing) rather than as somehow representative of certain potential causes of the outcome.
or as indicators. The variable outcome instructions determined whether the maximum impact score was 10 or 20. Cue status was manipulated on a within-subjects basis. There were five cues (see Table 1). During the compound phase, Cue A was always presented simultaneously with Cue T and Cue K was always presented together with Cue L. Both compounds were always followed by the outcome (i.e., tank destruction). A fifth cue, Cue M, was always presented on its own and was never followed by the outcome. During the elemental phase, Cue A was presented on its own and was always followed by the outcome; Cue M was also presented in isolation and was never followed by the outcome. Experiments 1 and 2 differed only with regard to the order of the compound and elemental phase. In Experiment 1, the elemental phase preceded the compound phase (forward blocking); in Experiment 2, the compound phase was presented before the elemental phase (backward blocking). Because Experiments 1 and 2 only differed with regard to the order of the compound and elemental phase, the procedure for both experiments is described in the same section.

### Method

#### Participants

In Experiment 1, 40 first-year psychology students at the University of Leuven participated for course credit. In Experiment 2, 23 first-year psychology students at the University of Leuven and 17 first- and second-year psychology students at the University of Southampton participated for course credit. Within each experiment, participants were randomly assigned to the different conditions.

#### Stimuli

The experiments were run on IBM-compatible PCs. A custom-made Turbo Pascal 7.0 program was used to present the instructions and stimuli and to register the ratings. Students in Leuven received Dutch instructions, and students in Southampton received an English translation of these instructions. On the 15" SVGA screens, a tank was 4 cm long and 2 cm wide. It moved in a continuous manner from the left to right side of the screen on a straight line that was situated 10 cm from the top of the screen. It took about 6 s for the tank to get from the left to the right side of the screen. If the tank exploded, this always occurred 2 s after the tank appeared. Explosions were always located at a point 12 cm from the left side of the screen. This was after approximately one-third of the distance that the tank would travel if it did not explode. If a tank exploded, the tank disappeared from the screen and was replaced by 10 lines that gradually increased in length from 1 cm to 7 cm and then decreased in length until they disappeared. The lines diverged as they became longer, thus forming a fan-like shape. This explosion took about 1 s. Five rectangles of 3 cm wide and 2.5 cm high were situated at the bottom of the screen. The rectangles were numbered 1 to 5, 1 being the rectangle on the far left side of the screen, and 5 being the rectangle on the far right side. A cue was on when a solid white square measuring 2.7 × 2.3 cm appeared in the

<table>
<thead>
<tr>
<th>Experiment</th>
<th>Phase 1</th>
<th>Phase 2</th>
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<tbody>
<tr>
<td>1</td>
<td>A+, M−</td>
<td>AT+, KL+, M−</td>
</tr>
<tr>
<td>2</td>
<td>AT+, KL+, M−</td>
<td>A+, M−</td>
</tr>
<tr>
<td>3</td>
<td>A+, B−, M−</td>
<td>AT1+, BT2+, KL+, M−</td>
</tr>
</tbody>
</table>

Note: All types of trial were presented 10 times.
rectangle that represented the cue. Participants entered their ratings using the keyboard. All stimuli were
drawn with white lines on a black background.

Procedure

At the beginning of the experiment, participants who were assigned to the weapons group were given
the following instructions:

In this task, army tanks will ride across the computer screen. A tank can be destroyed by certain
weapons. Each weapon is represented as a square on the bottom of the screen. There are five
weapons and thus five squares.
When a weapon fires, you will see a white light appearing in the square that represents the weapon
that fires. Two weapons can fire simultaneously, that is, at the exact same moment in time. If that
happens and the tank is destroyed, you do not know which of the two weapons was responsible for
destroying the tank. Despite this, you have to determine FOR EACH WEAPON
SEPARATELY how likely it is that a tank will be destroyed when that weapon fires.
Each time weapons fire, you will receive information about the combined impact that all fired
weapons had on the tank. The larger the impact, the larger the chance that the tank will be
destroyed. Note that the maximal impact that can be measured corresponds to an impact score of
X.
You will see 50 trials. On the basis of what you see during these trials, you will have to determine
FOR EACH WEAPON SEPARATELY how likely it is that a tank will be destroyed when that
weapon fires.

Participants in the indicator condition received the following instructions:

In this task, army tanks will ride across the screen. On some occasions, a tank will be destroyed. There
are certain indicators that predict when a tank will be destroyed. Each indicator is repre-
sented as a square on the bottom of the screen. There are five indicators and thus five squares.
When an indicator is on, you will see a white light appearing in the square that represents the indi-
cator. Two indicators can light up simultaneously, that is, at the exact same moment in time. You
have to try to determine FOR EACH INDICATOR SEPARATELY how likely it is that a tank
will be destroyed after that indicator lights up.
Apart from the fact that you will see whether the tank is destroyed, you will also receive verbal
information on the screen that tells you whether the tank was destroyed. After a tank is destroyed,
the message: IMPACT 10/X will appear on the screen. If the tank was not destroyed, the mes-
sage: IMPACT 0/X will appear on the screen.
You will see 50 trials. On the basis of what you see during these trials, you will have to determine
FOR EACH INDICATOR SEPARATELY how likely it is that a tank will be destroyed after that
indicator lights up.

For half of the participants in each group, the maximum impact X was 10, and for the other participants it
was 20. After the participants had read the instructions, a screen appeared on which the five squares were
visible, as was the horizontal line on which the tank would ride. The experimenter briefly repeated the
instructions while pointing at the relevant sections of the screen. Presentations started after the partici-
pant indicated that he or she had fully understood the instructions.
The compound phase consisted of 10 AT+ trials, 10 KL+ trials, and 10 M– trials. The elemental
phase consisted of 10 A+ trials and 10 M– trials. There was no break between the two phases. In Experi-
mence 1, the elemental phase was presented first, and in Experiment 2 the compound phase was presented
The order of the trials within each phase was determined randomly for each participant separately. Which square functioned as which cue was also determined randomly for each participant separately. When a cue lit up, a solid white square appeared in the square that functioned as that cue. The square was presented for 300 ms, during which time the tank kept on moving at the same speed as previously. If a tank explosion occurred, it occurred immediately after the solid white square disappeared. At the same time the message “IMPACT 10/X” appeared on the screen, where X stands for the maximum impact score. This message remained on the screen for 3 s. If the tank did not explode, the message “IMPACT 0/X” appeared on the screen until the tank, which drove on, had reached the right side of the screen. The intertrial interval was 3 s.

After observing all 50 trials, participants were asked to judge for each cue how likely it was that a tank would be destroyed if that weapon fired (weapon condition) or if that indicator lit up (indicator condition). We chose this question because it could be formulated in an identical way for both weapons and indicators, thus making the weapon and indicator conditions as similar as possible apart from instructions relating to the nature of the cues. Participants entered a score between “0” and “100”. A score of “0” meant “very unlikely”, a score of “100” meant “very likely”. All participants first rated the cue that was represented by Rectangle 1 (the rectangle on the far left side), then the cue represented by Rectangle 2, and so on. They gave their rating by typing a number between 0 and 100. During this rating phase, the rectangles and horizontal line were presented on the screen in the same way as during the compound and elemental phase. A 10-cm rating scale, ranging from 0 (very unlikely) to 100 (very likely), was also present on the screen together with the question “How likely is tank-destruction if weapon X fires?” (weapon condition) or “How likely is tank-destruction if indicator X lights up?”.

Results

The mean ratings for the five cues in the four conditions of Experiments 1 and 2 are shown in Tables 2 and 3 respectively. We first calculated a blocking score for each participant by subtracting the rating for Cue T from the mean of the ratings for Cues K and L. If this score is significantly higher than zero, one can conclude that the ratings of Cue T are significantly lower than the mean rating for Cues K and L and thus that blocking has occurred. These blocking scores were submitted to an Experiment (1, forward blocking or 2, backward blocking) × Cue Instructions (weapons or indicators) × Outcome instructions (maximum impact of 10 or 20) factorial analysis of variance (ANOVA). Because none of the effects involving experiment approached significance, all Fs < 1, we dropped this variable from the analyses. The analyses

<table>
<thead>
<tr>
<th>Cue</th>
<th>Maximal impact</th>
<th>T M SD</th>
<th>A M SD</th>
<th>K M SD</th>
<th>L M SD</th>
<th>M M SD</th>
<th>M SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weapons</td>
<td>20</td>
<td>6 12</td>
<td>93 16</td>
<td>39 16</td>
<td>46 15</td>
<td>1 1.6</td>
<td>37** 18</td>
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<tr>
<td></td>
<td>10</td>
<td>39 10</td>
<td>100 1</td>
<td>48 5</td>
<td>50 6</td>
<td>0 0</td>
<td>10 29</td>
</tr>
<tr>
<td>Indicators</td>
<td>20</td>
<td>51 31</td>
<td>96 13</td>
<td>56 29</td>
<td>60 29</td>
<td>4 13</td>
<td>6.5 18</td>
</tr>
<tr>
<td></td>
<td>10</td>
<td>55 28</td>
<td>100 0</td>
<td>55 28</td>
<td>56 26</td>
<td>0 0</td>
<td>1 20</td>
</tr>
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</table>

**p < .001.
reported here were performed on the data of both experiments but the results of the ANOVAs for each experiment separately are also reported. In addition, a priori t tests were performed to test the presence of blocking in the various conditions. In these and all further experiments, the significance level was set at \( p < .05 \). The \( p \) values are only reported in the case of marginally significant effect (\( .05 < p < .10 \)).

The Cue Instructions × Outcome Instructions ANOVA revealed a clear main effect of cue instructions, \( F(1, 76) = 17.84; \) Experiment 1, \( F(1, 36) = 9.06; \) Experiment 2, \( F(1, 36) = 8.15. \) A priori t tests showed that blocking was significant when cues were described as being weapons, \( t(39) = 5.00; \) Experiment 1, \( t(19) = 3.31; \) Experiment 2, \( t(19) = 3.80, \) but not when cues were described as being indicators, \( t(39) < 1; \) Experiments 1 and 2; \( t < 1. \) The main effect of outcome instructions was also significant, \( F(1, 76) = 8.88; \) Experiment 1, \( F(1, 36) = 3.45, p = .07; \) Experiment 2, \( F(1, 36) = 5.52, \) resulting from the fact that blocking was significant when the maximum impact score was 20, \( t(39) = 6.09; \) Experiment 1, \( t(19) = 4.43; \) Experiment 2, \( t(19) = 4.10, \) but not when the maximum impact score was 10, \( t(39) < 1.40; \) Experiments 1 and 2, \( t < 1. \) Although the interaction between both variables did not reach significance, \( F(1, 76) = 1.46; \) Experiment 1, \( F(1, 36) = 2.20, \) blocking was only significant when cues were described as weapons and the maximum impact was 20, \( t(19) = 9.31, \) marginally significant when cues were indicators and the maximum impact was 20, \( t(19) = 1.87, p = .08, \) not significant when cues were weapons and the maximum impact was 10, \( t(19) = 1.58, \) and not significant when cues were indicators and the maximum impact was 10, \( t(19) = 0.70 \) (also see Tables 2 and 3). Finally, a priori tests showed that the effect of outcome instructions was significant when cues were weapons, \( t(38) = 2.46; \) Experiment 1, \( t(18) = 1.23; \) Experiment 2, \( t(18) = 1.69, \) and approached significance when cues were indicators, \( t(38) = 1.70, p = .10; \) Experiment 1, \( t(18) = 1.69; \) Experiment 2, \( t < 1. \)

**Discussion**

The results showed that the nature of the outcomes and the cues had a clear impact on the magnitude of forward (Experiment 1) and backward (Experiment 2) blocking. Blocking was larger when participants were led to believe that the tank explosion (i.e., the outcome) did not

<table>
<thead>
<tr>
<th>Cue instructions</th>
<th>Maximal impact</th>
<th>( T )</th>
<th>( A )</th>
<th>( K )</th>
<th>( L )</th>
<th>( M )</th>
<th>Mean blocking score</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>( M )</td>
<td>( SD )</td>
<td>( M )</td>
<td>( SD )</td>
<td>( M )</td>
<td>( SD )</td>
<td>( M )</td>
</tr>
<tr>
<td>Weapons</td>
<td>20</td>
<td>6 16</td>
<td>86 21</td>
<td>42 12</td>
<td>42 12</td>
<td>0 0</td>
<td>36** 17</td>
</tr>
<tr>
<td></td>
<td>10</td>
<td>32 29</td>
<td>92 24</td>
<td>30 25</td>
<td>47 25</td>
<td>2 4</td>
<td>17 46</td>
</tr>
<tr>
<td>Indicators</td>
<td>20</td>
<td>53 28</td>
<td>99 3</td>
<td>64 25</td>
<td>55 28</td>
<td>0 0</td>
<td>6.5 13</td>
</tr>
<tr>
<td></td>
<td>10</td>
<td>66 30</td>
<td>94 16</td>
<td>59 28</td>
<td>60 27</td>
<td>10 28</td>
<td>–7 21</td>
</tr>
</tbody>
</table>

**\( p < .001. \)
Blocking was also significantly stronger when cues were described as weapons than when cues were said to be indicators.

The significant effect of outcome instructions suggests that our participants adhered to the logic outlined by Cheng (Cheng, 1997; Cheng & Holyoak, 1995; Waldmann, 2000). If outcomes always occur to a maximal extent on both A+ and AT+ trials, participants are reluctant to conclude that T is unrelated to the outcome because they cannot verify whether T leads to an increase in the intensity or rate of the outcome. A+ trials only seem to depress the ratings of T when participants can verify that T does not influence the intensity or rate of the outcome, as is the case when the outcome occurs to the same submaximal extent on A+ and AT+ trials.

In the Introduction we argued that the effect of outcome instructions on blocking would be more pronounced when cues were weapons than when cues were indicators. Although the effect of outcome instructions was significant only in the weapon condition, the interaction between cue instructions and outcome instructions was not significant. The present results therefore do not provide strong evidence for the hypothesis that outcome instructions have a different impact on blocking when cues are potential causes of the outcome than when the cues are merely indicators of the outcome.

There was, however, a clear main effect of cue instructions on blocking. The blocking effect was significantly stronger when cues were said to be weapons than when cues were described as indicators. Even though we attempted to make the instructions as similar as possible in the two conditions apart from the instructions relating to the nature of the cues, there were some other differences that were as such not related to the nature of the cues but that could also have had an impact on blocking. Most importantly, instructions in the weapons condition put more emphasis on the competition between different causes. In this condition, participants were told that if two weapons fire at the same time and the tank was destroyed “you do not know which of the two weapons was responsible for destroying the tank” (see Dickinson et al., 1984; and Shanks, 1985, for similar instructions). In the indicator condition, however, participants were merely told that “two indicators can light up simultaneously, that is, at the exact same moment in time”. Even though participants in both conditions were clearly told that they would have to make a judgement for each cue separately, it is possible that the instructions encouraged competition between cues (and thus blocking) more in the weapons condition than in the indicator condition. We therefore conducted a third experiment in which the instructions for the weapon and indicator conditions were matched even more closely. If the effect of cue instructions was due to the difference with regard to the nature of the cues (weapons or indicators), then we should be able to replicate the effect of cue instructions even when the weapon and indicator instructions stressed competition between cues to the same extent.

The aim of Experiment 3 was not only to replicate the effect of cue instructions under more controlled conditions but also to further explore the effects of cue instructions. First, we examined the effect of cue instructions on both blocking and reduced overshadowing. At a procedural level, reduced overshadowing (see Miller, Barnet, & Grahame, 1995, p. 376) is highly similar to blocking. Whereas in a blocking procedure A+ trials are presented in combination with AT+ trials, a reduced overshadowing procedure involves the presentation of B– trials together with BT+ trials. On the basis of probabilistic contrast models, one can expect that the B– trials will increase the ratings for Cue T relative to the ratings of control cues that are only
presented in compound (e.g., KL+) irrespective of whether the cues are described as weapons or indicators. In a blocking situation as implemented in Experiments 1 and 2 (A+ and AT+), participants are faced with the problem that the outcome always occurs on both A+ and AT+ trials. In such cases the outcome of the appropriate probabilistic contrast does not provide a good estimate of the relation between Cue T and the outcome (Cheng, 1997; Cheng & Holyoak, 1995). As was argued by Cheng (1997), participants can overcome this problem if the outcomes are continuous events that occur at a submaximal rate. However, they can do so only if the cues are causes but not if cues are indicators because only causes should affect the intensity of the outcome (see earlier).

However, in a reduced overshadowing situation (B– and BT+), the outcome does not always occur within the focal set. Because there is no problem with ceiling effects, the appropriate probabilistic contrast, $p(O/B,T) - p(O/B,\sim T) = 1 - 0 = 1$, should provide a valid estimate for the relation between T and the outcome. Because the outcome of the probabilistic contrast for T is 1, T should receive a high contingency rating. Assuming that participants adopt a probabilistic approach both when cues are weapons and when cues are indicators, they should infer with some degree of confidence that T is related to the outcome regardless of whether cues are weapons or indicators.

A second additional aim of Experiment 3 was to examine the effect of cue instructions on confidence ratings. After participants rated the relation between a cue and the outcome, they were asked to indicate how confident they were that their contingency rating was accurate. According to recent formulations of the probabilistic contrast model, participants should be confident about their contingency judgements if they can calculate an appropriate probabilistic contrast and if the boundary conditions for interpreting the outcome of the contrast are met (Cheng, 1997; Cheng & Holyoak, 1995). In a reduced overshadowing situation (B–, BT+), this is the case regardless of whether cues are weapons or indicators. Participants should thus always be confident in their rating for T. In a blocking situation (A+, AT+), the outcome of the probabilistic contrast will only be informative if cues are weapons and the outcome occurs to a submaximal extent. In such a situation, participants should be confident in their rating for T. When cues are indicators, however, participants should be unsure about their rating for T.

EXPERIMENT 3

Given the similarity of the effects of cue and outcome instructions on forward (Experiment 1) and backward (Experiment 2) blocking, we now only used a forward blocking design. A second simplification of the design was that we only used outcomes that occurred to a submaximal extent. A final major difference with Experiments 1 and 2 was that we now examined both blocking and reduced overshadowing. Table 1 shows that during the first phase, participants saw three types of trials A+, B–, and M–. The second phase consisted of four types of trial: AT1+, BT2+, KL+, and M–. Blocking would be evidenced by lower ratings for T1 than for K and L, and reduced overshadowing would be revealed by higher ratings for T2 than for K and L. As in Experiment 1, half of the participants were informed that the cues were weapons whereas the other participants were told that the cues were indicators.
Method

Participants

A total of 42 first-year psychology students at the University of Leuven participated for course credit. None had participated in the previous experiments. An equal number of students were assigned to both conditions.

Materials and procedure

The materials used and the procedure followed were the same as those in Experiments 1 and 2 except on the following points. First, there now were seven cues and thus seven squares at the bottom of the screen. Second, instructions (Dutch) were the same except that the sentence: “If this happens and the tank is destroyed, you do not know which of the two indicators was the actual predictor of the tank explosion” was inserted in the instructions of the indicator condition. This sentence was inserted after the sentence “Two indicators can light up simultaneously, that is, at the exact same moment in time”. Third, there were more trials than in Experiments 1 and 2. During the first phase, there were 10 A+ trials, 10 B– trials, and 5 M– trials. The second phase consisted of 10 AT1+, 10 BT2+, 10 KL+, and 10 M– trials. Fourth, the maximal impact was 20 for all participants. Finally, participants were also asked to express their confidence in each of the likelihood ratings. After they entered their rating for a cue, a 10-cm rating scale ranging from 0 (very unsure) to 100 (very sure) was presented together with the question “How sure are you?”.

Results

Table 4 displays the mean likelihood and confidence ratings for the seven cues in the two conditions of Experiment 3. As in the previous experiments, we calculated for each participant a blocking score by subtracting the likelihood rating for Cue T from the mean of the likelihood ratings for Cues K and L. Blocking is indicated by a positive blocking score. We also calculated a reduced overshadowing score by subtracting the mean likelihood rating for Cues K and L from the mean likelihood rating of Cue T2. As such, reduced overshadowing is evidenced by a positive reduced overshadowing score. To study the effects of cue instructions on the confidence ratings for T1 and T2, we also calculated a blocking and reduced overshadowing score using the confidence ratings. The blocking score corresponded to the mean confidence rating for T1 minus the mean confidence ratings for K and L, whereas the reduced overshadowing score equalled the mean confidence rating of T2 minus the mean confidence rating for K and L. A positive blocking score thus expresses a higher confidence in the likelihood rating for the blocked Cue T1 than in the likelihood ratings for the control Cues K and L. Likewise, a positive reduced overshadowing score reveals a higher confidence in the likelihood rating for Cue T2 than in the likelihood ratings for the control Cues K and L. We then performed a Cue Instructions (weapons or indicators) × Type of Effect (blocking or reduced overshadowing) ANOVA for the likelihood judgements and for the confidence judgements separately.

The ANOVA performed on the blocking and reduced overshadowing scores for likelihood ratings revealed a main effect of type of effect, $F(1, 40) = 7.41$, but no main effect of cue instructions, $F(1, 40) = 2.04$. Most important, the interaction between cue instructions and type of effect was significant, $F(1, 40) = 8.21$. A priori $t$ tests showed that the blocking effect was larger when cues were weapons than when they were indicators, $t(40) = 2.70$, but that cue instructions did not have a significant effect on reduced overshadowing, $t < 1$. Further $t$ tests
### TABLE 4
Mean likelihood ratings and confidence ratings as a function of cue instructions and cue in Experiment 3

<table>
<thead>
<tr>
<th>Cue instructions</th>
<th>Rating</th>
<th>T1</th>
<th>T2</th>
<th>A</th>
<th>B</th>
<th>K</th>
<th>L</th>
<th>M</th>
<th>Blocking</th>
<th>Reduced overshadowing</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weapons</td>
<td>Likelihood</td>
<td>12</td>
<td>24</td>
<td>78</td>
<td>30</td>
<td>81</td>
<td>27</td>
<td>9</td>
<td>21</td>
<td>42</td>
</tr>
<tr>
<td></td>
<td>Confidence</td>
<td>85</td>
<td>22</td>
<td>86</td>
<td>23</td>
<td>88</td>
<td>25</td>
<td>86</td>
<td>24</td>
<td>56</td>
</tr>
<tr>
<td>Indicators</td>
<td>Likelihood</td>
<td>34</td>
<td>26</td>
<td>85</td>
<td>29</td>
<td>93</td>
<td>20</td>
<td>4</td>
<td>12</td>
<td>49</td>
</tr>
<tr>
<td></td>
<td>Confidence</td>
<td>56</td>
<td>29</td>
<td>80</td>
<td>24</td>
<td>90</td>
<td>23</td>
<td>87</td>
<td>25</td>
<td>65</td>
</tr>
</tbody>
</table>

**p < .001; *p < .05.
(see Table 4) revealed that blocking was significant when cues were weapons, \( t(20) = 5.55 \), but only marginally significant when cues were indicators, \( t(20) = 2.00, p = .06 \). Reduced overshadowing, however, was significant both when cues were weapons, \( t(20) = 6.08 \), and when cues were indicators, \( t(20) = 10.34 \).

The analysis of the blocking and reduced overshadowing effects in the confidence ratings revealed a main effect of cue instructions, \( F(1, 40) = 7.38 \), a main effect of type of effect, \( F(1, 40) = 11.88 \), and a significant interaction between both variables, \( F(1, 40) = 9.86 \). A priori \( t \) tests showed that the interaction was due to a significant effect of cue instructions on the blocking confidence score, \( t(40) = 2.70 \), but not on the reduced overshadowing confidence score, \( t(40) = 1.40 \). Further \( t \) tests revealed that participants were more confident in their rating for T1 (i.e., the blocked cue) than in their ratings for K and L when cues were weapons, \( t(20) = 4.33 \), but not when cues were indicators, \( t(20) = –1.08 \). Participants were, however, more confident in their rating for T2 (i.e., the reduced overshadowing cue) than in their ratings for K and L both when cues were weapons, \( t(20) = 4.32 \), and when cues were indicators, \( t(20) = 2.40 \).

Discussion

Experiment 3 allowed us to investigate whether the effect of cue instructions on blocking as observed in Experiments 1 and 2 was due to differences in the nature of the cues or to the fact that the weapon instructions in those experiments put more emphasis on competition amongst cues than did the indicator instructions. Despite the fact that the weapons and indicator instructions were now comparable with regard to their emphasis on competition among cues, blocking was still more pronounced when cues were weapons than when cues were indicators.

Whereas blocking was significantly smaller for indicators than for weapons, reduced overshadowing occurred to the same extent for both types of cue. The reduced overshadowing results are important for a number of reasons. First, they argue against a configural explanation of the fact that blocking effects were not significant in the indicator conditions of our experiments. Williams et al. (1994) demonstrated that if participants regard the compound cue AT as a new unique cue rather than as a cue consisting of two separate cues, training with one element of the compound cue (i.e., A) will not affect responding to the other element of the compound cue (i.e., T). The fact that we did observe reduced overshadowing in the indicator condition shows that participants did not regard BT2 as a configural cue. Because BT2+ trials differed from AT1+ trials only with regard to the associative history of B and A, it is therefore likely that they also did not regard AT1 as a unique configural cue.

Second, one might argue that blocking does not occur when cues are indicators because under these conditions, participants tend to give ratings on the basis of the outcome of unconditional—that is, \( p(O/T) \), rather than conditional probabilities, \( p(O/A.T) – p(O/A.~T) \). If, however, participants use the outcome of unconditional probabilities when cues are indicators, reduced overshadowing should also not occur because the unconditional probabilities for T2 and the control Cues K and L are all equal to 1. Third, the significant effect of reduced overshadowing in the indicator group also argues against the hypothesis that some residual differences between the weapons and indicator instructions were responsible for the difference in blocking between the two groups. Why would such potential differences prevent one form of cue comparison (i.e., blocking) but not another form (i.e., reduced overshadowing)?
some situations, failures to find blocking when cues are indicators might be due to subtle aspects of the instructions or to the fact that indicators encourage configural processing or encourage judgements on the basis of unconditional probabilities. However, the fact that we observed reduced overshadowing in the indicator condition suggests that the absence of blocking in Experiment 3 cannot be explained in such ways.

The data do fit rather well with recent formulations of the probabilistic contrast model. As was mentioned earlier, these models postulate that participants will be reluctant to make likelihood judgements for Cue T if the outcome is always present on A+ and AT+ trials. In the present experiment, participants could overcome this problem because the outcome was a continuous event that occurred at a submaximal extent. However, this should only help when cues are weapons but not when cues are indicators because only weapons can be assumed to have a causal impact on the extent to which the outcome occurs (see earlier). Therefore, blocking should occur only when cues are weapons but not when cues are indicators, as was observed. Note, however, that the model is not compatible with the fact that blocking was marginally significant when cues were indicators (but see later).

The probabilistic contrast model also predicted that reduced overshadowing would be unaffected by the nature of the cues. Regardless of whether cues are weapons or indicators, participants should be able to interpret the probabilistic contrast for T2 on the basis of B– and BT2+ trials because the outcome does not always occur within the relevant focal set of events. Therefore, reduced overshadowing should occur regardless of the nature of the cue. Finally, the confidence data were also largely in line with the predictions of the probabilistic contrast model. Confidence ratings for T1 and T2 were higher than those for the control Cues K and L whenever the model predicted that participants should be able to interpret the probabilistic contrast for T1 and T2 (i.e., Weapon T1, Weapon T2, and Indicator T2).

GENERAL DISCUSSION

The phenomenon of blocking has had a major impact on theories of human contingency judgements. The present experiments demonstrate that the nature of the cues and outcomes can modulate blocking. First, blocking was more robust when outcomes did not always occur at a maximal extent on the A+ and AT+ trials. Second, blocking (but not reduced overshadowing) was stronger when the cues were presented as potential causes of the outcomes rather than as mere indicators or predictors of the outcome. Note that the results do not allow one to conclude that blocking can only be found when outcomes occur at a submaximal level and when cues are causes. In all experiments, the blocking effect was marginally significant when cues were (non-causal) indicators. Although non-significant, the blocking effect was also in the expected direction when cues were weapons and outcomes did always occur at a maximal level. One could therefore expect that significant blocking effects can be found under those conditions given sufficiently powerful tests. Nevertheless, the observation that the nature of the outcomes and cues can modulate blocking is important for at least two reasons.

First, our results shed some new light on the existing evidence about blocking in human contingency learning. We are aware of at least two series of studies that failed to produce reliable (forward) blocking effects (Glaudt, 2000; Vandenbroucke, 2000). Interestingly, both researchers used tasks in which the cues were described as predictors of an outcome that
always occurred to a maximal extent on A+ and AT+ trials. The present results suggest that the absence of blocking effects in these studies might have been due to the nature of the cues and outcomes that were used. One could, however, argue that many other studies have demonstrated blocking effects even though cues were indicators, and/or outcomes always occurred to a maximal extent on the crucial trials, or that there might also be unreported studies that failed to produce blocking despite the fact that the cues were causes of submaximal outcomes. There are two replies to these arguments. First, as was mentioned earlier, we do not want to argue that cues must be causes and outcomes must occur at a submaximal rate in order for blocking to occur, nor do we want to argue that blocking will always be found when cues are causes of submaximal outcomes. Our data merely suggest that blocking effects are more robust when these conditions are met. Therefore, the chances of finding significant blocking effects could depend on the nature of the cues and outcomes.

Second, one might be tempted to overestimate the amount of evidence for blocking when cues are indicators and/or outcomes always occur at a maximal extent on the crucial trials. In many studies, blocking and reduced overshadowing were confounded (e.g., Chapman, 1991; Chapman & Robbins, 1990; Dickinson & Burke, 1996; Williams et al., 1994). Rather than examining blocking by comparing the ratings for a blocked cue T (A+, AT+) with the ratings of control cues that were only presented in compound (KL+), these studies tested blocking by comparing the ratings of a blocked cue T1 (A+, AT1+) with the ratings of a second target cue T2 that was involved in a reduced overshadowing manipulation (B–, BT2+). Although lower ratings for T1 than for T2 allow for the conclusion that the contingency judgement for a target cue depends on the relation between the outcome and an alternative cue with which the target cue was paired, it is unclear whether the difference between T1 and T2 is due to the fact that the A+ trials depressed the rating for T1 (i.e., blocking) or that the B– trials increased the ratings for T2 (i.e., reduced overshadowing), relative to a baseline situation in which neither A+ nor B– trials were presented. Experiment 3 demonstrated that reduced overshadowing does occur even when cues are indicators. It is interesting to note that Vandenbroucke (2000), who used indicators and submaximal outcomes, did not observe blocking but did find reduced overshadowing. Likewise, in a series of backward blocking studies where cues were potential causes but outcomes always occurred at maximal extent on A+ and AT+ trials, Larkin et al. (1998) found strong evidence for reduced overshadowing (or unovershadowing) but only weak evidence for blocking (but see Wasserman & Berglan, 1998). The data of Experiment 3, Vandenbroucke (2000), and Larkin et al. (1998) at least allow for the possibility that many previous demonstrations of blocking with indicators and/or maximal outcomes were actually demonstrations of reduced overshadowing rather than blocking.

One could argue that in animal conditioning studies, blocking is a robust finding even though the cues (conditioned stimuli) that are used in these studies are stimuli such as lights and tones that only predict but do not cause the outcome (unconditioned stimulus, e.g., food or shock). One straightforward reply to this argument is that the present experiments were primarily designed to inform us about contingency learning in humans. Although there are striking similarities between human contingency learning and Pavlovian conditioning in animals, some caution is needed when comparing results from these two lines of study. Moreover, although most human participants would agree that cues such as lights do not cause outcomes such as electric shocks, it is risky to make inferences about how animals interpret the link between such stimuli.
To summarize this point, our results demonstrate that the magnitude of blocking in human contingency learning depends on outcome and cue properties. Although the results do not allow for definite conclusions about when blocking will and will not occur, they do inform us about the conditions under which blocking is most likely to occur in human contingency learning and can help us understand inconsistencies between the results of previous studies. Therefore, regardless of the theoretical implications, the results provide an important empirical contribution to the literature on human contingency learning.

We do believe, however, that our results also inform us about the processes that underlie human contingency learning. The fact that the nature of the cues and outcomes can have an effect on blocking is difficult to explain on the basis of associative models such as the Rescorla–Wagner model (Rescorla & Wagner, 1972). As was noted by Shanks, Lopez, Darby, and Dickinson (1996) and Waldmann (2000), whether or not participants think of the cues as possible causes of the outcome should be irrelevant according to associative learning theories. Likewise, it is difficult to see how associative models can explain the observation that the magnitude of blocking depended on information about the maximal level of outcome that could be measured. Regardless of that maximal level, all participants saw the same events, and the intensity of outcome was always 10 on the A+ and AT+ trials. Therefore, the value of the parameters in associative models such as the Rescorla–Wagner model (see Equation 2) should be the same regardless of the maximal level of the outcome, and the cues should acquire the same associative strength.

One could, however, assume that the perceived intensity of the outcome decreases with increases in the maximal level of the outcome. In the Rescorla–Wagner model, outcome intensity can be modelled by varying the value of $\lambda$ (see Equation 2) in such a way that $\lambda$ increases with increases in the intensity of the outcome (see Miller et al., 1995, p. 367). But even with these added assumptions, the Rescorla–Wagner model still does not provide a straightforward explanation of our results. Simulations show that with an equal number of A+ and AT+ trials, the associative strength of T will be higher with an intense outcome than with a less intense outcome. This is in line with the observation that T receives a higher rating when the maximal outcome is 10 (i.e., intense outcomes) than when it is 20 (i.e., less intense outcomes). However, the associative strength of the control cues K and L will also be higher with intense outcomes than with less intense outcomes. As a result, the Rescorla–Wagner model predicts that blocking (i.e., the mean associative strength of K and L minus the associative strength of T) should be larger when the outcome is 10 than when the outcome is 20, which is opposite to what we observed. Therefore, the model does not appear to be able to accommodate our results, even if one makes assumptions about how information about the maximal level of the outcome can be modelled.

Whereas the present results are difficult to explain on the basis of the Rescorla–Wagner (1972) model, they are largely compatible with recent formulations of the probabilistic contrast model (Cheng, 1997; Cheng & Holyoak, 1995). First, the fact that blocking effects were

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3In these simulations, all parameters in Equation 2 were kept constant except for $\lambda$, which was set at 1 for the condition in which the maximal impact was 10 but was given the value .50 for the condition where the maximal impact was 20. We also made sure that the associative strength of A was not at asymptote after the A+ trials. When A has the maximal associative strength after Phase 1, T cannot gain associative strength on the subsequent trials regardless of whether the maximal impact is 10 or 20.
more reliable when outcomes occurred at a submaximal level supports the idea that participants are reluctant to interpret the outcomes of probabilistic contrasts when the normative boundary conditions for interpreting these contrasts are not met, whereas they do interpret these contrasts when the boundary conditions are fulfilled. Second, Cheng (1997) pointed out that when outcomes always occur within the relevant focal set, participants will interpret the probabilistic contrast provided that the outcome occurs at a submaximal intensity and cues are causes. This idea is compatible with the observation that in the present experiments (where outcomes always occurred on A+ and AT+ trials), blocking was more pronounced when cues were causes than when cues were indicators. Although one could think of other reasons why blocking is more pronounced with causal than with indicator cues (see earlier), only the probabilistic model seems to be able to explain why cue instructions affected blocking but not reduced overshadowing: In a reduced overshadowing design (B−, BT+), the outcome does not always occur within the focal set for T. Therefore, reduced overshadowing should be found regardless of whether cues are weapons or indicators. Finally, whenever participants can calculate and interpret an appropriate probabilistic contrast, confidence in judgements should be high. This prediction was confirmed by the data of Experiment 3.

One should note, however, that although the fit between the results and the predictions of recent probabilistic contrast models was good, it was not perfect. First, in all experiments, blocking approached significance when cues were indicators even though the outcomes always occurred on the A+ and AT+ trials. Second, in Experiments 1 and 2, there was a tendency for a blocking effect when cues were weapons and the outcome always occurred at a maximal level. Together with previous studies that demonstrated blocking with cues as causes and maximal outcomes (e.g., Wasserman & Berglan, 1998), this finding is incompatible with the model of Cheng (1997) because her model is formulated in such a way that blocking should never be found when outcomes always occur at a maximal level.

One could, however, argue that the results are compatible with a less strict version of the probabilistic contrast model. According to this process interpretation of the model, all participants do make contingency judgements on the basis of the outcome of appropriate probabilistic contrasts. Only some participants, however, fully take into account the restrictions that apply when interpreting these contrasts. When an outcome always occurs at a maximal level on A+ and AT+ trials, several interpretations are possible, and participants should therefore be uncertain about their judgement for Cue T. Whereas some participants might express this uncertainty by giving a rating near the midpoint of the scale, others might still base their judgement on the outcome of the probabilistic contrast and give a low rating for T even though they know that other interpretations are possible. The confidence ratings that were observed in Experiment 3 seem to support this version of the probabilistic contrast model. Although the likelihood ratings for T1 tended to be lower than likelihood ratings for the control cues K and L, confidence ratings were the same for all three cues. This suggests that even the participants who did make judgements on the basis of the probabilistic contrast for T1 were aware of the problems in doing so.

The adapted version of the probabilistic contrast model is, of course, entirely post hoc and depends on yet more auxiliary process assumptions. Nevertheless, it can be disconfirmed. The revised probabilistic contrast model is compatible with the observation of blocking effects when outcomes always occur to a maximal extent and/or cues are indicators. But when blocking occurs under those conditions, confidence in the judgements for the blocked cue should be
low. When outcomes do not always occur to a maximal extent, and cues are causes, however, blocking effects should be stronger, and participants should be highly confident in their contingency judgements for the blocked cue.

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