The role of memory for compounds in cue competition

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Abstract

Revisions of common associative learning models incorporate a within-compound association mechanism in order to explain retrospective cue competition effects (e.g., [Dickinson, A., & Burke, J. (1996). Within-compound associations mediate the retrospective revaluation of causality judgements. Quarterly Journal of Experimental Psychology, 49B, pp. 60–80.]). These models predict a correlation between memory for compounds (as a measure for the strength of within-compound associations) and retrospective cue competition but not forward cue competition. This was indeed found in a study of [Melchers, K. G., Lachnit, H., & Shanks, D. (2004). Within-compound associations in retrospective revaluation and in direct learning: A challenge for comparator theory. Quarterly Journal of Experimental Psychology, 57B, pp. 25–54.]. We argue that a higher-order reasoning account of causal learning can also explain the evidence for the role of within-compound associations in cue competition. Moreover, this account predicts that if making inferences during the learning stage is impeded, a correlation between memory for compounds and forward cue competition should be found as well. The results of a new study confirmed this prediction.

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Cue competition in Human Causal Learning (HCL) refers to the fact that causal judgments about a target cue T also depend on information about a competing cue A with which T co-occurred. There are several types of cue competition effects. In this paper, we will focus on forward and backward blocking, reduced overshadowing and unovershadowing. Forward blocking refers to the fact that a causal judgement about a cue T is lower when AT+ trials (i.e., cue A and cue T presented together and followed by the outcome) are preceded by A+ trials (A followed by the outcome) than when only AT+ trials are presented. Backward blocking refers to the same finding, but with the AT+ trials preceding the A+ trials. In a reduced overshadowing design, AT+ trials are preceded by A− trials (cue A not followed by the outcome). Causal judgements for cue T will be higher than when only AT+ trials are presented. Unovershadowing refers to the same effect, but with the order of events reversed (first AT+ trials, then A− trials). Forward blocking and reduced overshadowing are both forward cue competition effects whereas backward blocking and unovershadowing are retrospective cue competition effects or retrospective revaluation effects.

At the time when retrospective revaluation was discovered (Kaufman & Bolles, 1981; Shanks, 1985), prevailing associative learning models (e.g., Rescorla & Wagner, 1972; Wagner, 1981) could not account for it because these models do not allow that the associative strength of a cue can change on trials where the cue is absent. As a consequence, the associative strength of cue T cannot change on the A+ trials or A− trials in a backward blocking or unovershadowing design, respectively. To explain retrospective cue competition effects, these associative learning models have been extended with a within-compound association mechanism (e.g., Dickinson & Burke, 1996). Without going into detail about the specific implementations of the different models, a within-compound association mechanism states that the associative strength of a cue that is activated but absent changes in the opposite direction of cues that are present. An absent cue can be activated by a present cue through a within-compound association. For instance, T will become associated with A as a result of the AT+ trials. As a consequence, T will be expected but absent on the subsequent A+ or A− trials and the associative strength of cue T will decrease on A+ trials in a backward blocking design and increase on A− trials in a reduced overshadowing design.

There is a lot of evidence for the role of within-compound associations in HCL. Dickinson and Burke (1996; see also Larkin, Aitken, & Dickinson, 1998) compared forward and retrospective cue competition in two conditions. In one condition, the target cues were consistently paired with the same competing cues (consistent condition), while in the other condition the target cues were inconsistently paired with different competing cues (variable condition). As expected, retrospective cue competition was found only in the consistent condition but not in the variable condition. This difference between conditions was not found for forward cue competition. Dickinson and Burke attributed these results to the fact that within-compound associations were stronger in the consistent pairing condition. The strength of within-compound associations should influence retrospective cue competition but not forward cue competition because only retrospective cue competition effects depend on the formation of within-compound associations. Note that in the variable condition, there were 27 different compound cues (competing and target cues presented together) each presented once, while in the consistent condition there were only 9 different compound cues each presented three times. As a consequence, it seems reasonable to assume that memory for compound cues was better in the consistent condition than in the variable condition.
Aitken, Larkin, and Dickinson (2001) used another manipulation to interfere with the formation of within-compound associations. During compound trials, they first presented cue A (or cue T), then asked participants to perform a simple mental arithmetic task during a short interstimulus interval and then presented the target cue T (or cue A). This manipulation again affected retrospective cue competition but not forward cue competition. Importantly, retrospective cue competition was less pronounced for participants with relatively poor memory for the compound cues after the test stage.

In two other studies, the strength of within-compound associations was assessed by measuring memory for compound cues. Wasserman and Berglan (1998) found retrospective cue competition only for participants who recognized the compounds at the end of the experiment and Melchers, Lachnit, and Shanks (2004) found a correlation between retrospective cue competition (but not forward cue competition) and memory for compounds. As de Houwer and Beckers (2002) pointed out, the evidence for the role of within-compound associations is commonly regarded as unique and strong evidence for the role of associative models of HCL. In this paper, however, we argue that a higher-order reasoning account can also explain these findings. We also present further evidence that supports a higher-order reasoning account of the role of memory for compounds in cue competition.

In recent years, there has been increasing evidence in support of a higher-order reasoning account of cue competition (e.g., de Houwer, Beckers, & Vandorpe, 2005; Lovibond, Been, Mitchell, Bouton, & Frohart, 2003; Waldmann, 2000). A central tenet of this account is that cue competition is a product of controlled inferences about the causal status of cues. In a forward blocking design (A+, AT+), for example, participants can infer on the AT+ trials that T is not a cause of the outcome if they can verify that T does not add anything to the effect of A (that is, the outcome is as intense or likely to occur when only A is present as when both A and T are present). In a backward blocking design, a similar inference can be made on the A+ trials provided that participants still remember the AT+ trials during the A+ trials. In a reduced overshadowing design (A−, AT+), subjects can infer on the AT+ trials that T is a cause of the outcome if they remember that A on its own was not followed by the outcome. Similarly, in an unovershadowing design, an inference can be made on the A− trials of the second learning stage provided that participants still remember the AT+ trials of the first learning stage (for a more detailed overview of a higher-order reasoning account and the evidence in support of it, see de Houwer et al., 2005).

As may be clear from the above, a higher-order reasoning account is also capable of explaining the evidence for the role of within-compound associations in cue competition (also see Mitchell, Kiledar, & Lovibond, 2005, who independently arrived at the same conclusion). In order to make inferences on the A+ trials in a backward blocking design and on A− trials in an unovershadowing design, one has to remember the compound trials AT+. Because the strength of within-compound associations has always been assessed by measuring memory for compounds (e.g., Melchers et al., 2004; Wasserman & Berglan, 1998) or has been manipulated in such a way that memory for compounds was affected (e.g., Dickinson & Burke, 1996), prior studies do show that retrospective cue competition depends on memory for compounds. In the case of forward cue competition on the other hand, participants can make inferences during the AT+ trials in the second learning stage if they remember the A+ (blocking) or A− (unovershadowing) trials of the first learning stage. As such, they do not have to remember any compounds to make causal inferences, and memory for compounds and forward cue competition should not be correlated.
Therefore, the existing evidence for the role of within-compound associations cannot discriminate between an associative and a higher-order reasoning account of cue competition.

A higher-order reasoning account, however, does make specific predictions concerning the role of memory for compounds in forward cue competition. It predicts that memory for compounds will play a role in forward cue competition when making inferences is impeded during the learning stage and can only be made during the test stage. When inferences are made during the test stage, participants need to remember both the A+ or A– and the AT+ trials. The aim of this study was to test this prediction.

Our experiments were based on the design of Melchers et al. (2004) and Table 1. Melchers et al. used a food allergy paradigm wherein cues are foods and the outcome is an allergic reaction. In order to measure retrospective cue competition, AB+, CD+ (first learning stage) and A+, C– (second learning stage) trials were presented. Retrospective cue competition corresponded to the mean causal rating of D minus the mean causal rating of B. Similarly, E+, G– (first learning stage) and EF+, GH+ (second learning stage) trials were presented. Forward cue competition corresponded to the mean causal rating of H minus the mean causal rating of F.

In order to prevent participants from making inferences during the learning stage, the cover story of the food-allergy paradigm was not presented until after the learning stage (Experiment 2). Participants saw combinations of foods and either the letter A or the letter G, without knowing that the letter A stood for the occurrence of an allergic reaction and the letter G for absence of an allergic reaction. Without knowing that the presented foods were actually possible causes of an allergic reaction, participants could not make causal inferences during the learning stage. One could argue that this procedure does not completely exclude the possibility that (some) participants make inferences during the learning stage. This is indeed true. However, the more participants engage in reasoning during the learning stage, the smaller the correlation between memory for compounds and cue competition should be. Thus the possibility that (some) participants make inferences during the learning stage goes against the prediction of a higher-order reasoning account.

Except for the manipulation of the instructions, there is one important way in which our experiment differs from that of Melchers et al. (2004). Unlike Melchers et al., we presented the letters A and G as outcomes instead of the full text ‘allergic reaction’ and ‘no allergic reaction’. In order to assure that we could replicate the original finding of Melchers et al. (i.e., a correlation between memory for compounds and retrospective cue competition but no correlation between memory for compounds and forward cue competition) with the specific procedural implications of our study, we first conducted an experiment with standard instructions before the learning stage.

Table 1
Design of the experiments (see also Melchers et al., 2004)

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<tr>
<th></th>
<th>First Stage</th>
<th>Second Stage</th>
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<tbody>
<tr>
<td>Retrospective cue competition</td>
<td>AB+, CD+</td>
<td>A+, C–</td>
</tr>
<tr>
<td>Forward cue competition</td>
<td>E+, G–</td>
<td>EF+, GH+</td>
</tr>
<tr>
<td>Fillers</td>
<td>I–, K–</td>
<td>I–, KL–</td>
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</table>

Note. All letters refer to different foods. For each letter, there were two different foods in the design, resulting in 24 cues and 24 events. The ‘+’ stands for occurrence of the outcome, which was an allergic reaction, and the ‘–’ for non-occurrence of the outcome.
Experiment 1

Methods

Participants
Forty-one first-year psychology students at Ghent University participated for course credit. All were native Dutch speakers.

Design, stimuli, and materials
The design (see Table 1) was identical to that of Melchers et al. (2004). In the first stage, \(AB^+, CD^+, E^+, G^-, IJ^-,\) and \(K^-/C^0\) trials were presented. In the second stage, \(A^+, C^-/C^0, EF^+, GH^+, I^-/C^0,\) and \(KL^-/C^0\) trials were presented. Two different foods were assigned to each cue, resulting in 12 different events in each learning stage. Each stage consisted of four blocks. Within each block, every event was presented twice. There were thus 24 events in each block, 96 in each stage, and 192 in the entire experiment. The sequence of the events within a block was randomized. There were no breaks between blocks or stages. The cues were presented as coloured pictures of foods against a white background, with the name of the food under the picture in a black colour. The following foods were used (translated from Dutch): apples, avocado, bananas, blueberries, broccoli, carrots, cherries, coffee, eggs, fish, grapes, ice-cream, kiwi, lemon, meat, mushrooms, nuts, pears, peppers, popcorn, potatoes, strawberries, toast, and tomatoes. As outcomes, the letters A, standing for allergic reaction, and G, standing for no allergic reaction, were presented. We choose the letter A because it is the first letter of the Dutch expression ‘Allergische reactie’ (allergic reaction) and the letter G because it is the first letter of the Dutch expression ‘Geen allergische reactie’ (no allergic reaction).

The task was presented on a Pentium I PC and implemented using a custom made Inquisit program. Four different random allocations of the foods to the different cues were used and counterbalanced across participants.

Procedure
At the beginning of the experiment, standard learning instructions appeared on the screen (see Appendix A). After reading the instructions, participants could press on the ‘go further’ button (this was the letter ‘v’ on the keyboard) to start the learning stage. Each trial started with the presentation of the pictures of the food(s) and the name(s) of the food(s) under the picture(s) in the centre of the screen. After 2000 ms, the letter A or G was added to the screen underneath the picture(s) and the name(s) of the food(s). After 4000 ms, the message ‘press v to go further’ appeared on the screen. After participants pressed on the key ‘v’, a white screen appeared during 2000 ms. Then the next trial started. After all 192 trials, standard test instructions (see Appendix A) appeared on the screen. After reading the instructions and a press on the ‘go further’ button, the first food appeared in the centre of the screen together with a Likert scale from 1 (never causes an allergic reaction) to 10 (always causes an allergic reaction) underneath the food. The participants could make their rating by a click with the mouse on a digit of the rating scale. After this click, a white screen was presented during 1000 ms. Then the next food appeared together with the Likert scale. The 24 different foods were presented in a random order that was determined separately for each participant.
After completing their causal ratings, participants completed two memory tests. One was a test of their memory for cues presented elementally (i.e., cues that were presented on their own during the learning stage, e.g., cue A), and one was a test of their memory for cues presented always in compound (i.e., cues that were never presented on their own during the learning stage, e.g., cue B). The order of these two memory tests was counterbalanced across participants.

During both memory tests, the foods appeared in the centre of the screen. During the memory test for cues presented elementally, participants decided whether the food was followed by the letter A or the letter G during the learning stage. They did this by a press on the respective keys of the keyboard. During the test that assessed the memory for cues presented in compound, participants decided with which food the target foods (i.e., cue B, D, F, and H) were consistently paired during the learning stage. For this purpose, participants had a sheet with the pictures of all 24 foods with each food assigned to a letter. Participants pressed the key that corresponded to the letter of the food that they thought was paired with the presented food.

**Results and discussion**

**Ratings**

First, we analysed the causal ratings of the different experimental cues. Mean ratings for the different cues with standard deviations are given in Table 2. The ratings of the cues that were presented alone were in line with expectations. That is, causal ratings of cue A and cue E were high and causal ratings of cue C and cue G were low. The causal ratings of the target cues that were not presented alone (B, D, F, and H) were analyzed by means of a 2 (Cue Type: blocked cues B and F versus reduced overshadowing cues D and H) × 2 (Order: forward cues F and H versus retrospective revaluation cues B and D) repeated measures ANOVA. This analysis revealed a main effect of Cue Type, \( F(1,40) = 105.14, \text{MSE} = 6.34, \ p < .001 \), and a significant interaction of Cue Type and Order, \( F(1,40) = 55.61, \text{MSE} = 3.26, \ p < .001 \). The influence of Order was not significant, \( F(1,40) < 1 \). To examine the significant interaction of Cue Type and Order, we compared the causal ratings of the target cues for forward and retrospective cue competition separately with paired samples \( t \)-tests. These tests revealed that the causal ratings of the blocked cues were significantly lower than the causal ratings of the reduced overshadowing cues, \( t(40) = 5.12, \ p < .001 \), and \( t(40) = 13.23, \ p < .001 \), for retrospective and forward cue competition, respectively. The Cue Type × Order interaction, however, shows that

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<th>Cue</th>
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<td>B</td>
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<td>F</td>
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retrospective cue competition (measured as the causal rating of cue D minus the causal rating of cue B) was smaller than forward cue competition (measured as the causal rating of cue H minus the causal rating of cue F).

Correlations
Our most important analyses concerned the correlations between memory for compounds on the one hand and forward and retrospective cue competition on the other hand. We first constructed a memory measure for each cue competition effect as in the study of Melchers et al. (2004). The memory scores for the target cues F and H (for forward cue competition) and B and D (for retrospective cue competition) were added. The memory for compound cues was coded as +1 if memory was correct and as 0 if memory was incorrect. Because there were two different foods assigned to each cue, the memory measures for compound could vary between 0 and 4. The mean value of the measure of memory for compounds was 1.98 (SD = 1.13) and 2.44 (SD = 1.45) for forward and retrospective cue competition, respectively. The difference between both measures was significant, t(40) = 2.55, p < .05. Because the distribution of the memory scores was skewed, we calculated non-parametric Spearman’s ρ correlations. In accordance with Melchers et al. (2004), these were one-tailed. We found no (positive) correlations between memory for compounds and forward cue competition, ρ = .03. For retrospective cue competition, on the other hand, the correlation was significant, ρ = .76, p < .001.

Discussion
The aim of Experiment 1 was to replicate the results of the study of Melchers et al. (2004) with a slightly adapted procedure. Clearly, this replication was successful. We did not find a correlation between memory for compounds and forward cue competition but did observe a positive significant correlation between memory for compounds and retrospective cue competition. As argued in the introduction, these findings are predicted both by an associative account and a higher-order reasoning account of cue competition in human causal learning. The results of Experiment 1 serve as a starting point for our crucial instructional manipulation in Experiment 2. In this experiment, we present the standard learning instructions after the learning stage (instead of before the learning stage as in Experiment 1). Under these conditions, a higher-order reasoning account predicts that memory for compounds should be correlated not only with retrospective cue competition, but also with forward cue competition.

Experiment 2

Methods

Participants
Eighty first-year psychology students at Ghent University participated for course credit. All were native Dutch speakers.

Design, stimuli, and materials
The design, the stimuli, and materials were identical to Experiment 1.
Procedure

The procedure was identical to the procedure of Experiment 1, except for the instructions before and after the learning stage. The instructions (translated from Dutch) before the learning stage were as follows:

First, on each trial you will see certain foods. Sometimes there is one food and sometimes there are two foods. Always look carefully at the foods that appear on the screen. You will also always see the letter A or the letter G. There are 192 of such trials. Look attentively and try to memorize as well as possible what is presented on the screen. Afterwards, we will ask you questions about what you have seen.

In order to motivate our participants for this awkward task, we also gave them additional motivational instructions. We told them that the results of the task were correlated with IQ and exam results. Furthermore, the participants entered the test room in pairs and they were told that the one with the best results would receive 5€.

The instructions after the learning stage were the standard learning instructions before the learning stage of Experiment 1 (see Appendix A), adjusted for the past tense (e.g., ‘If the letter A appeared’ instead of ‘If the letter A appears’). At the beginning of these standard learning instructions, the following sentence was added (translated from Dutch):

Before we will ask questions concerning your knowledge about what you have seen, you will first get additional important information you will need to answer the questions.

Results

Ratings

Mean ratings for the different experimental cues with standard deviations are given in Table 3. As in Experiment 1, causal ratings of cue A and cue E were high and causal ratings of cue C and cue G were low. The causal ratings of the target cues that were not presented alone (B, D, F, and H) were analyzed by means of a 2(Cue Type: blocked cues B and F versus reduced overshadowing cues D and H) × 2(Order: forward cues F and H versus retrospective revaluation cues B and D) repeated measures ANOVA. This analysis revealed a main effect of Cue Type, $F(1, 79) = 62.63, MSE = 6.92, p < .001$, and a significant interaction of Cue Type and Order, $F(1, 79) = 7.41, MSE = 4.18, p < .01$. The influence of Order was not significant, $F(1, 79) < 1$. To examine the significant interaction of Cue Type and Order, we compared the causal ratings of the target cues for forward and retrospective cue competition

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separately with paired samples \( t \)-tests. These tests revealed that the causal ratings of the blocked cues were significantly lower than the causal ratings of the reduced overshadowing cues, \( t(79) = 4.17, p < .001 \), and \( t(79) = 8.90, p < .001 \), for retrospective and forward cue competition, respectively. The Cue Type \( \times \) Order interaction, however, shows that forward cue competition was stronger than retrospective cue competition.

**Correlations**

Memory scores and correlations were computed as in Experiment 1. The mean memory for compound scores were 2.75 (\( SD = 1.24 \)) and 2.89 (\( SD = 1.23 \)) for forward and retrospective cue competition, respectively. The difference between both scores was not significant, \( t(79) < 1 \). We found a significant correlation between memory and forward cue competition, \( r = .20, p < .05 \). The correlation between memory and retrospective cue competition was also significant, \( r = .24, p < .05 \).

**Discussion**

The aim of Experiment 2 was to test the prediction of a higher-order reasoning account that memory for compounds would be correlated not only with retrospective cue competition but also with forward cue competition when making inferences during the learning stage was impeded. The results of Experiment 2 confirmed this prediction.

**General discussion**

We started this paper by pointing out that the existing studies about the role of within-compound associations in retrospective cue competition (Aitken et al., 2001; Dickinson & Burke, 1996; Melchers et al., 2004; Wasserman & Berglan, 1998) cannot differentiate between an associative and a higher-order reasoning account of cue competition. The strength of within-compound associations in these studies was measured by memory for compounds or was manipulated in such a way that also memory for compounds was affected. Therefore, these studies showed that retrospective cue competition depends on memory for compounds, which is an observation that is compatible with a higher-order reasoning account of cue competition. Note that this point is crucial because evidence for the role of within-compound associations in cue competition was until now reported as unique support for revised associative learning models.

A higher-order reasoning account is not only compatible with the existing evidence for the role of within-compound associations or memory for compounds in retrospective revaluation, it also makes a specific prediction regarding the role of memory for compounds in forward cue competition. If making inferences during the learning stage is impeded, a higher-order reasoning account predicts a correlation between memory for compounds and forward cue competition. In accordance with this prediction, we indeed found a significant correlation between an index of memory for compounds and forward cue competition when the learning instructions were presented after the learning stage (as a manipulation impeding inferences during the learning stage, Experiment 2). This was not the case when learning instructions were presented before the learning stage (Experiment 1).

Associative models that attribute cue competition effects to a selective learning mechanism (e.g., Dickinson & Burke, 1996; Rescorla & Wagner, 1972; van Hamme & Wasserman, 1994; Wagner, 1981) cannot accommodate this result. Associations between foods and
either the letter A or the letter G were formed during the learning stage. Causal judgements of
the different cues should have been based on these associations irrespective of whether
participants remembered the compound cues or not. The comparator hypothesis (e.g.,
Denniston, Savastano, & Miller, 2001), however, which emphasizes that cue competition
effects are due to a performance effect, can account for this correlation. According to the
comparator hypothesis, a causal judgement does not depend on the absolute strength of
the association between a certain cue and outcome, but on the relative strength of that
cue compared to the associative strength of its comparator cue. This comparison, however,
is possible only if the comparator cue is activated. In other words, this comparison depends
on within-compounds associations (as a mechanism for activating the appropriate compar-
ator cue) or by extension on memory for compounds as a measure for these within-comp-
pound associations. The comparator hypothesis, however, cannot explain the fact that
memory for compounds does not play a role in forward cue competition when the cover
story of the experiment is given before the learning stage (e.g., Melchers et al., 2004). Accord-
ing to the comparator hypothesis, within-compound associations are always important to
make an appropriate comparison between relative associative strengths. In sum, associative
models with emphasis on the learning stage (e.g., Dickinson & Burke, 1996; van Hamme &
Wasserman, 1994) cannot account for the correlation between memory for compounds and
forward cue competition when making inferences during the learning stage is impeded, while
associative models with emphasis on the test stage (e.g., Denniston et al., 2001) cannot
account for the lack of correlation between memory for compounds and forward cue com-
petition when making inferences during the learning stage is possible. The entire set of evi-
dence concerning the role of memory for compounds in forward cue competition can be best
explained by a higher-order reasoning account. To obtain forward cue competition, memory
for compounds is necessary if inferential reasoning is prevented until after the learning stage,
but is not important when inferences can be made during the learning stage.

One could argue, however, that the correlation between memory for compounds and
forward cue competition is compatible with associative accounts in terms of individual
learning ability differences. Better learners probably have better memory for compounds
and will show more cue competition than poorer learners. As a consequence, both vari-
ables will be correlated with each other, but this does not necessarily mean that forward
cue competition is due to better memory for compounds. However, a closer inspection
of the data reveals that this explanation in terms of differences in individual learning abil-
ity is not very plausible. According to a higher order reasoning account, forward cue com-
petition should be correlated more strongly with memory for the compounds involved in
reduced overshadowing (i.e., MemGH) than with memory for the compounds involved in
forward blocking (i.e., MemEF). That is, the causal status of a reduced overshadowing cue
can be inferred with certainty while the causal status of a blocked cue X cannot be when
the outcome is always merely present on A+ and AX+ trials (e.g., de Houwer, Beckers, &
Glaudt, 2002; Lovibond et al., 2003). Therefore, reduced overshadowing and by exten-
sion memory for the compounds involved in reduced overshadowing should have contrib-
uted more to forward cue competition than forward blocking. Additional analyses indeed
showed that forward cue competition correlated more strongly with memory for the

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1 The design did not permit us to compute blocking and reduced overshadowing separately because there were
no overshadowing control cues. In recent studies at our laboratory, however, we indeed found that reduced
overshadowing was significantly stronger than forward blocking (Vandorpe & de Houwer, 2005, 2006).
compound involved in reduced overshadowing than with memory for the compound involved in forward blocking, $r = .20, p < .05,$ and $r = .12, p > .15,$ respectively. Importantly, however, the mean memory score for reduced overshadowing ($1.36, SD = 0.77$) was, if anything, lower than the mean memory score for forward blocking ($1.39, SD = 0.74$). Thus, although memory for forward blocking was, if anything, better than memory for reduced overshadowing, it was to a lesser extent correlated with forward cue competition than reduced overshadowing, which is at variance with an explanation in terms of individual learning abilities.

Finally, the correlation between memory for compounds and retrospective cue competition was also significant in our studies. This finding is in line with both higher-order reasoning accounts and associative learning models. Nevertheless, the observed correlation between memory for compounds and retrospective cue competition in Experiment 2 was lower than in the study of Melchers et al. (2004) and than in Experiment 1. However, an admittedly very tentative explanation in terms of a higher-order reasoning account seems feasible. Evidence from a recent study at our laboratory (Vandorpe & de Houwer, 2006) suggests that retrospective reasoning processes are more prone to task complexity than forward reasoning processes. It seems also reasonable to assume that giving the instructions after the learning stage makes the task more complex than giving the instructions before the learning stage. As a consequence, the smaller correlation between memory for compounds and retrospective cue competition observed when the instructions are given after the learning task may have been due to some participants failing to make the appropriate retrospective inferences even though they had good memory for the different events. This could also explain why retrospective cue competition was smaller than forward cue competition, despite the fact that memory for the retrospective events was at least as good as memory for the forward events.

To conclude, the evidence about the role of within-compound associations in cue competition does not uniquely support associative models but can also be explained by a higher-order reasoning account. Moreover, the significant correlation between memory for compounds and forward cue competition that we obtained, provides unique support for a higher-order reasoning account.

**Appendix A**

*Learning Instructions (translated from Dutch)*

Try to imagine that you are a doctor. One of your patients suffers from allergic reactions after eating certain foods. To detect which foods lead to an allergic reaction, the patient has eaten specific foods on different days followed by a check whether an allergic reaction occurred or not. In a moment, you will see the results of these daily allergic tests one by one on the screen. On every trial, you will first see what the patient had eaten that day. On some days, the patient ate only one food; on other days he ate two foods. Each time, you will also get information about the allergic reaction the patient showed. If the letter A appears, this means that there was an allergic reaction after eating the presented food. If the letter G appears, this means that there was no allergic reaction after eating the food. Your task is to determine for each food separately if it leads to an allergic reaction in the patient. Note that if the patient ate two foods and there was an allergic reaction, then you do not know which of the two foods was responsible for the allergic reaction. You
nevertheless have to determine for every single food to what extent it causes an allergic reaction in your patient on basis of all the information you get. Notice that only the presented information can help you. The task is to determine to which extent the foods cause an allergic reaction in this specific patient. Your personal experiences with the foods or occasional knowledge about the properties of the foods are not relevant and cannot help you. Only the presented information matters.

**Test instructions (translated from Dutch)**

Now you have to judge for each food separately to which extent it causes an allergic reaction in the patient. You can do this by giving a score between 1 and 10, where a score of ‘1’ means that the food never causes an allergic reaction and a score of ‘10’ means that the food always causes an allergic reaction. Thus the higher your score, the more likely it is that the food causes an allergic reaction in the patient.

**References**


