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Evidence for the interchangeability of an avoidance behavior and a negative occasion setter

Mieke Declercq and Jan De Houwer
Ghent University, Ghent, Belgium

Recent research on avoidance behavior provided evidence that such behavior can function as a negative occasion setter. We tested this hypothesis further by investigating whether the modulatory function of a stimulus occasion setter transfers selectively to a relation previously modulated by an avoidance behavior, and whether the modulatory function of an avoidance behavior transfers selectively to a relation previously modulated by a stimulus occasion setter. The three experiments reported in this article provided evidence to support this hypothesis. Furthermore, the results of Experiment 1 suggested that the presence of counterconditioning trials is not a necessary condition for an avoidance behavior to function as a negative occasion setter. All three reported experiments support the occasion-setting account of avoidance behavior.

Avoidance behavior is an instrumental response that prevents the occurrence of an aversive event. It is a common phenomenon in life, since a great deal of our activity is performed to avoid the occurrence of negative or aversive stimuli. In a typical study of avoidance learning, a warning signal (A) is presented and followed by an aversive unconditioned stimulus (US), unless the participant performs a designated response (R). For example, a tone (A) is presented and is followed by an electric shock (US), unless the participant presses a certain key (R). Recently, a new theoretical approach was proposed by De Houwer, Crombez, and Baeyens (2005; see Gray, 1987; Lovibond, 2006; Mowrer, 1947; and Seligman & Johnston, 1973, for other accounts of avoidance learning). Their cognitive theory was based on the observation that avoidance behavior and negative occasion setting are quite similar at the structural level (for a review on the literature of occasion setting, see Holland, 1992, or Schmajuk & Holland, 1998). In negative occasion setting, the occasion setter signals whether a certain stimulus (also called the target) will be followed by the US. If the occasion setter is presented together with the target, the US will not follow, but it will if the occasion setter is not presented. Avoidance behavior, in its turn, also involves a feature negative discrimination: If the avoidance response is performed, the warning signal will not be followed by the US, but it will be if the avoidance response is not performed. From this structural perspective, avoidance learning and negative occasion setting are similar. The only difference is that in the former the occasion setter is a behavior, whereas in the latter the occasion setter is a stimulus (e.g., a tone).

De Houwer et al. (2005) investigated whether avoidance behavior is similar to negative occasion setting at a functional level as well. According to Holland (1992), an occasion setter possesses three properties. First of all, it modulates responding to the target. In the case of negative occasion setting, the participants learn that the presence of the US after the presentation of the target is less probable when the occasion setter is presented, whereas the absence of the occasion setter indicates that the US will be presented after the target. This implies that conditioned responding to the target will be stronger when the occasion setter is absent than when it is present. Whereas the property of modulation is not unique to occasion setters (e.g., even presenting a novel stimulus together with a target can modulate responding to the target), the other two properties are. The first of these unique properties is that a negative occasion setter modulates responding to the target independent of its own relation with the US. This means that even when there is a positive contingency between the negative occasion setter and the US, this contingency has no effect on the modulation of the negative occasion setter. In the literature, this property is called *resistance against counterconditioning*. The second unique property of an occasion setter is *selective transfer*. This means that the modulating powers of an occasion setter transfer to other targets, but in a selective manner; they will especially transfer to targets that also have been involved in occasion-setting training. For example, suppose that stimulus A is followed by the US, unless occasion setter S is present, and that stimulus B is followed by the US, unless occasion setter T is present, and that stimulus C is followed by the US on half of the trials in which it is

M. Declercq, miekee.declercq@ugent.be

presented. The property of selective transfer predicts that S would modulate responding to B more than to C.

Although resistance against counterconditioning and selective transfer are considered to be the defining properties of an occasion setter, we should note that these properties do not always co-occur (Goddard & Holland, 1997; Skinner, Goddard, & Holland, 1998). Also, most of the reported evidence is restricted to animal experiments (but see Baeyens, Vansteenwegen, Hermans, Vervliet, & Eelen, 2001; Young, Johnson, & Wasserman, 2000, for examples of occasion-setting studies in humans). Finally, there is no general agreement about the processes responsible for the modulatory power of an occasion setter being resistant against counterconditioning and transferring selectively. One explanation is in terms of the modulation of the activity of associations in memory (e.g., Holland, 1983; Ross & Holland, 1981). Another option is in terms of configural stimulus representations (e.g., Wilson & Pearce, 1989, 1990). Nevertheless, the properties of resistance to counterconditioning and selective transfer remain the only criteria to determine whether a stimulus or a behavior functions as a negative occasion setter.

To test the hypothesis that avoidance behavior can function as a negative occasion setter, De Houwer et al. (2005) therefore examined whether an avoidance behavior possesses properties unique to negative occasion setting. In their experiment, three different warning signals were presented. Warning signals A and B were always followed by the US, whereas the third warning signal, C, was followed by the US on only half of the trials on which C was presented. In a second learning phase, two avoidance responses were possible, one after warning signal A and the other after warning signal B. In a third learning phase, additional counterconditioning trials for the first avoidance behavior were presented (i.e., participants had to perform the first avoidance behavior, which was followed by the presentation of the US). In a test phase, participants indicated how likely it was that the US would be presented in certain situations. The results of this test phase showed that avoidance behavior not only modulated conditioned responding to the warning signal with which it was trained (trained modulation), but also that modulation was resistant against counterconditioning and that the modulatory powers of the avoidance behavior transferred selectively to the other relation that was involved in avoidance training. De Houwer et al. thus concluded that avoidance behavior can function as a negative occasion setter, in that it has the same functional properties.

The studies reported in this article further investigate the occasion-setting theory of avoidance behavior. If we assume that an avoidance response acts as a negative occasion setter, the function of a negative stimulus occasion setter and an avoidance response should be interchangeable. This means that the modulatory function of an avoidance behavior should transfer selectively to a warning signal–US relation that had previously been modulated by a negative occasion setter and that the modulatory function of a negative occasion setter should transfer selectively to a warning signal–US relation that had previously been modulated by avoidance behavior. Experiment 1 is based on the original experiment of De Houwer et al. (2005), but instead of using two avoidance behaviors, we used only one avoidance behavior, and we also introduced a negative stimulus occasion setter (a tone).

EXPERIMENT 1

Method

Participants. Thirty-six students at Ghent University participated in the experiment in exchange for course credits.

Stimuli and Materials. The experiment was run on an IBM-compatible 486 computer with a 14-in. screen, and was controlled by a Turbo Pascal 5.0 program that operated in graphics mode. As warning signals, a white circle (2-cm diameter), triangle (base, 2 cm; height, 2 cm), and square (2 × 2 cm) were used. As negative stimulus occasion setter, a tone of 1000 Hz was used that was presented for 1,000 msec. A red X (2 × 2 cm) served as US. The visual stimuli were presented in a central frame, 20 cm wide and 13 cm high, that appeared in the center of the screen. At the top of this central frame was a second frame, 9 cm wide and 1.5 cm high, in which a message appeared when a key was available on a particular trial. At the bottom of the central frame, a third frame, 5 cm wide and 1.5 cm high, was drawn, inside which a white horizontal bar (2 × 0.5 cm) was presented when the participants had given a valid response. As the avoidance response, the participants could press the space bar. Participants gave their ratings by typing in a number between 0 (*very unlikely*) and 100 (*very likely*). All instructions and messages were presented in Dutch.

Procedure. Participants took part individually in a dimly lit room. After signing an informed consent form, participants took their place at a distance of approximately 60 cm from the computer screen. Participants received written instructions in Dutch. They were told that their main task was to prevent the appearance of a red X on the screen and that they were able to do so by pressing the space bar when this key was available. Finally, they were told that at the end of the experiment, there would be a test of what they had learned about the conditions under which the red X appeared on the screen. After the participant indicated that he or she had read the instructions, the experimenter demonstrated how the responses should be executed. On these trials, neither warning signals nor USs were presented and the only available key was the space bar.

The first learning phase (see Table 1) consisted of four trials in which warning signal A was presented and followed by the US (A+ trials), four trials in which warning signal B was presented and followed by the US (B+ trials), two trials in which warning signal C was presented and followed by the US (C+ trials), and two trials in which warning signal C was presented and was not followed by the US (C− trials). Which shape (circle, square, or triangle) was assigned to which warning signal was randomly determined at the beginning of the experiment. On all these trials, the shape appeared 1,500 msec after the onset of the central frame and remained on the screen for 2,000 msec. The US was presented 3,000 msec after the shape disappeared and remained there for 1,500 msec. During the presentation of the US, ten 100-msec tones of decreasing frequency were presented, indicating failure. When the US was not presented, ten tones of increasing frequency were presented for 100 msec each, indicating success. The intertrial interval was 5,000 msec. The order of the trials was randomized for each participant separately. In this first learning phase, the space bar was not available. If participants did press the space bar, however, it had no influence on the presentation of the stimuli.

The second learning phase started immediately after the first one. In this phase, there were four trials in which warning signal A was presented and the space bar was available (AR− trials), four trials in which warning signal B was presented and the tone was presented (BT− trials), two C+ trials, and two C− trials. The C+ and C− trials were identical to those of the first learning phase. The AR− trials were identical to the A+ trials except on the following

Table 1
Summary of the Design of Experiments 1 and 2 and Mean US Expectancies and Standard Deviations for the Rating Phase

				Ratings Experiment 1***		Ratings Experiment 2***	
Phase 1	Phase 2	Phase 3	Test Phase	*M*	*SD*	*M*	*SD*
A+	AR−*	A+	A?	80.00	21.08	79.12	24.54
B+	BT−	B+	B?	70.56	28.85	73.75	30.73
C+	C+	C+	C?	55.14	25.62	55.75	20.74
C−	C−	C−	AR?	21.39	33.56	27.37	33.68
		AR−*	BR?	38.33	35.17	36.62	34.14
		BT−	CR?	29.58	25.00	28.50	23.15
		R+**	AT?	48.75	32.94	54.75	32.18
			BT?	31.67	34.04	28.00	35.10
			CT?	42.03	29.90	44.25	26.69
			R?	16.39	35.31	73.00	37.03
			T?	30.42	33.65	29.65	26.56

*The US was absent only when participants pressed the appropriate key. **These trials were presented only in Experiment 2. ***The mean US expectancy and standard deviation for the ratings are based on the data of all participants.

points: First, the message "the space bar is available" appeared on the screen, immediately after the shape disappeared, and remained on the screen for 2,000 msec. If participants pressed the space bar during the presentation of this message, a confirmation bar was presented for 1,000 msec. The trial then ended as a US-absent trial (see above). If the participant did not press the key, pressed the key before or after the presentation of the message, or pressed another key, the confirmation bar was not presented and the trial ended as a US-present trial (see above). The BT− trials were identical to the B+ trials, except on the following point: 1,000 msec after the shape disappeared, a tone of 1,000 msec was presented and the trial ended as a US-absent trial.

A third learning phase started immediately after the second one. In this third learning phase, participants saw four A+ trials, four B+ trials, four C+ trials, four C− trials, four AR− trials, and four BT− trials. These trials were identical to those presented in the first and second learning phase. After this third learning phase, instructions appeared on the screen that informed participants about the upcoming rating phase. Participants were told that different situations would be described and that they had to indicate how likely it was that a red X would be presented in these situations. They would be able to do this by entering a score between 0 (*very unlikely*) and 100 (*very likely*). Participants were told that they would receive no feedback about the correctness of their rating. They were also told that they had to give a second score with a value between 0 (very uncertain) and 100 (very certain) to indicate how certain they were about their rating on each situation. These confidence ratings were added for exploratory reasons only. On each rating trial, a description of the situation appeared at the top of the screen. For situations in which a warning signal and the response were present, the description read as follows: "If you see the [name of shape] and you press the space bar, how likely is it that the red X would be presented?" For situations in which a warning signal and the tone were presented, the description read as follows: "If you see the [name of shape] and you hear the tone, how likely is it that the red X would be presented?" For situations in which no tone was presented and the space bar was not pressed, the description read as follows: "If you see the [name of shape] and you do not press the space bar and you do not hear a tone, how likely is it that the red X would be presented?" For situations in which no shape was presented and the space bar was pressed, the description read as follows: "If you see no shape and you press the space bar, how likely is it that the red X would be presented?" And for situations in which no shape was presented and the tone was presented, the description read as follows: "If you see no shape and you hear the tone, how likely is it that the red X would be presented?" The description and the rating scale disappeared after participants entered their confidence rating; the next trial started 500 msec later. The order of these rating trials was determined randomly for each participant separately.

Results

Trained modulation. In line with De Houwer et al. (2005), we estimated trained modulation by calculating the difference between the US expectancy rating on the A and AR rating trials and the B and BT rating trials (i.e., [A − AR] and [B − BT]). An overview of the mean values and standard deviations of all the relevant indices can be found in Table 2. When we investigated modulation by the avoidance behavior (i.e., [A − AR]), a one-sample *t* test showed that this index was significantly different from zero [$t(35) = 8.49, p < .001$]. This means that participants expected the US less when the avoidance response was performed after the presentation of A than when A was presented and the response was not performed. Identical results were found for the specific modulation index for the tone (i.e., [B − BT]) [$t(35) = 5.22, p < .001$], indicating that the tone modulated responding to B.

Selective transfer. In order for trained modulation to transfer, modulation has to be present in the first place. Therefore, we included only the data of participants for whom the trained modulation indices for both R and T were larger than zero. As a result, the data of 17 participants were removed from further analyses. The means and standard deviations of all relevant transfer indices can be found in Table 2.

First of all, we investigated whether the modulatory power of T transferred to the warning signal–US relation that was modulated by the avoidance behavior (that for stimulus A). Therefore, we calculated a transfer index that was the difference between the US expectancy on the A and AT test trials (i.e., [A − AT]). A one-sample *t* test indicated that this transfer index was different from zero [$t(18) = 5.33, p < .001$]. Thus, transfer for the modulation was present for T. A second index for transfer of modulation was calculated that expressed the extent to which the avoidance behavior modulated responding to B (the stimulus that was accompanied by

Table 2
Mean US Expectancies and Standard Deviations for the Indices of Experiments 1 and 2

	Index	Experiment 1		Experiment 2	
		M	*SD*	*M*	*SD*
Trained modulation	A − AR	58.61	41.40	51.75	46.94
	B − BT	38.89	44.72	45.75	50.53
Transfer to other target	B − BR	49.47	34.52	56.46	40.63
	A − AT	47.10	38.52	33.96	36.32
Transfer to C	C − CR	32.37	39.59	29.58	27.42
	C − CT	14.21	43.37	10.00	30.22
Selective transfer targets	(B − BR)/B	0.60	0.39	0.58	0.44
	(A − AT)/A	0.47	0.62	0.37	0.37
Selective transfer C	(C − CR)/C	0.62	0.36	0.50	0.51
	(C − CT)/C	0.12	0.90	0.13	0.54

the stimulus occasion setter T). This index (i.e., [B − BR]) was different from zero [$t(18) = 6.25, p < .001$]. We also investigated whether T and R modulated responding to the partially reinforced stimulus C. The transfer index for T (i.e., [C − CT]) was not different from zero [$t(18) = 1.43, p = .17$], whereas the transfer index for R (i.e., [C − CR]) did differ from zero [$t(18) = 3.56, p < .005$].

To investigate whether the transfer was selective, we compared the transfer of modulation for the warning signal–US relations involved in occasion setting (A–US and B–US) with the transfer of modulation for the warning signal–US relation not involved in occasion setting (C–US). However, it was necessary to take the proportion rather than the absolute level of modulation, since the US expectancy after C ($M = 59.47$, $SD = 27.18$) was always lower than after A and B ($M = 81.05$, $SD = 15.62$) [$t(18) = -3.08, p < .01$]. First, we calculated a selective transfer index for the stimulus occasion setter T with regard to responding to A (i.e., [(A − AT)/A]) and to C (i.e., [(C − CT)/C]). A paired-samples *t* test indicated that these indices were significantly different [$t(17) = 2.76, p < .05$], demonstrating selective transfer of modulation. In a similar way, a relative transfer index was calculated for R with regard to responding to B (i.e., [(B − BR)/B]) and C (i.e., [(C − CR)/C]). These indices did not differ significantly [$t(17) = -0.23, p = .82$].

Although ratio scores were necessary to circumvent the problem of different baseline ratings for A, B, and C, these ratio scores themselves may cause other problems, especially when the denominator approaches zero. Therefore, we also tested selective transfer by comparing absolute difference scores rather than ratios. The results indicated that modulation by T did transfer selectively [$t(18) = 2.83, p < .05$], but modulation by R did not [$t(18) = 1.43, p = .17$]. Nevertheless, these effects need to be interpreted with caution because of the difference in baseline ratings for A, B, and C.

Discussion

The main finding of this experiment was that the modulatory power of the stimulus occasion setter T transferred more strongly to the A–US relation (the relation that was modulated by the avoidance behavior R) than to the C–US relation. This finding strongly suggests that R functioned as a negative occasion setter. The only difference between these two warning signal–US relations was that the A–US relation was signaled by R (i.e., A was followed by the US only when R was not performed), whereas the C–US relation was unsignaled (i.e., there was no signal that discriminated between C+ and C− trials). The fact that T modulated responding to A more than responding to C indicates that participants recognized that R signaled the A–US relation, just as T signaled the B–US relation. In other words, participants must have recognized that both R and T functioned as negative occasion setters.

However, we should note that the avoidance behavior did not show all the properties of an occasion setter. Unlike what was observed by De Houwer et al. (2005), the modulatory function of R did not transfer selectively to the relation involved in a negative occasion-setting training (i.e., B–US). One difference between the present study and that of De Houwer et al. is that our study did not include counterconditioning (R+) trials. In the absence of such counterconditioning trials, the behavior shown on AR− trials might simply indicate that R is an inhibitor of the US. If R functions as an inhibitor, it should modulate responding to all stimuli independent of whether the stimulus was involved in modulatory training. This could explain why we failed to find selective transfer for R. Although it is not clear how this alternative hypothesis could account for the observation that the modulatory function of T did transfer selectively to the A–US relation, we decided to run a second study in which R+ trials were added to the design. Such counterconditioning trials should prevent R from becoming an inhibitor of the US.

EXPERIMENT 2

Method

Participants. Forty participants took part in the experiment. They were paid according to how successful they were in avoiding the US (on average, €5).

Stimuli, Materials, and Procedure. Stimuli and materials were identical to those used in Experiment 1. The procedure was almost identical to the one used in Experiment 1. One difference concerned the instructions given at the beginning of the experiment: Because the participants were paid for their participation, they were told that at the beginning of the experiment they each would receive a certain amount of money but would lose €0.25 for every red X that appeared on the screen. The rest of the instructions were identical to those for Experiment 1. When the US was presented during the experiment, a message informing participants that they had lost €0.25 appeared at the top of the computer screen at the onset of the red X. The message disappeared after 1,500 msec. If the US was not presented, or was successfully avoided, a message informing participants that their credit remained unchanged appeared on the screen for 1,500 msec. Furthermore, in the third phase of the experiment, eight counterconditioning trials (R+ trials) were presented. On these trials, no warning signal was presented. Instead, the message "Press the space bar" appeared for 2,000 msec in the center of the screen, 3,500 msec after the onset of the central frame. If participants pressed the space bar during that time, the confirmation bar was presented for 1,000 msec and the trial ended as a US-present trial. If participants had not pressed the key during the 2,000 msec, the message "You need to press the space bar in order to continue" appeared on the screen and was accompanied by tones of 200 Hz that were each presented for 200 msec at intervals of 500 msec. The message disappeared only after the appropriate key was pressed. The trial then ended in the same way as a US-present trial would.

Results

Trained modulation. The modulation indices were calculated in the same way as were the modulation indices of Experiment 1; an overview of these and other indices can be found in Table 2. The modulation index for T did differ significantly from zero [$t(39) = 5.73$, $p < .001$], just as the modulation index for R did [$t(39) = 6.97$, $p < .001$]. This indicated that both the tone and the avoidance behavior modulated responding to the warning signal they were trained with.

Selective transfer. We included only participants with modulation indices for both R and T larger than zero (see Experiment 1). As a result, the data of 16 participants were removed from further analysis. First, we investigated the transfer of the modulatory function of T to the A–US relation previously modulated by R. This transfer index (i.e., [A − AT]) was different from zero [$t(23) = 4.58$, $p < .001$]. Second, we calculated the transfer index to see whether the modulatory function of the avoidance behavior transferred to the relation trained with the tone (i.e., [B − BR]). This index was also different from zero [$t(23) = 6.81$, $p < .001$]. We also examined the transfer of the modulatory function of the tone and the avoidance behavior with regard to responding to the partially reinforced stimulus C. The transfer index for the tone (i.e., [C − CT]) was not different from zero [$t(23) = 1.62$, $p = .12$]. However, the transfer index for the avoidance behavior (i.e., [C − CR]) did differ from zero [$t(23) = 5.28$, $p < .001$].

A paired samples *t* test indicated that the US expectancy after C ($M = 56.25$, $SD = 20.18$) was lower than the US expectancy after A and B ($M = 90.21$, $SD = 11.91$) [$t(23) = -6.59$, $p < .001$]. Therefore, we took the proportion rather than the absolute level of modulation to investigate selective transfer. We calculated an index for transfer of modulation that expressed the extent to which the tone modulated responding to A (i.e., [(A − AT)/A]), and compared it with the index that expressed the extent to which the tone modulated responding to C (i.e., [(C − CT)/C]). A paired samples *t* test showed that these indices were different from each other [$t(22) = 2.24$, $p < .05$]. Similarly, we compared the relative degree to which the avoidance behavior modulated responding to B (i.e., [(B − BR)/B]) and compared it with the relative degree to which it modulated responding to C (i.e., [(C − CR)/C]). A paired samples *t* test showed that these indices were not different from each other [$t(22) = 0.71$, $p = .49$].

As in Experiment 1, we also tested selective transfer by comparing absolute differences; the results indicated that modulation by T and modulation by R transferred selectively [$t(23) = 3.38$, $p < .01$, and $t(23) = 2.91$, $p < .01$, respectively]. However, one should keep in mind that the baseline ratings for A, B, and C were significantly different.

Discussion

As in Experiment 1, we found evidence that both the tone and the avoidance behavior modulated responding to the warning signal they were trained with. Furthermore, the modulatory powers of the tone transferred selectively toward the relation that was modulated by the avoidance behavior. This indicates that the function of an avoidance behavior and a negative stimulus occasion setter are interchangeable, and thus that the avoidance behavior functions as a negative occasion setter. It is also important to note that the modulation and transfer results of Experiment 1 were almost identical to those of Experiment 2, indicating that counterconditioning trials are not a necessity for an avoidance behavior to function as an occasion setter. The similarity of the modulation and transfer results cannot be attributed to the fact that the counterconditioning trials in Experiment 2 were ineffective. In Experiment 1, the mean US expectancy after performing R was 16.39. In Experiment 2, the mean US expectancy after R amounted to 73.00. This suggests that counterconditioning trials in Experiment 2 did influence responses to R. When we analyzed the data of Experiments 1 and 2 using experiment as a between-subjects variable, none of the effects was moderated by experiment.

EXPERIMENT 3

Although we can conclude that the avoidance behavior functioned as a negative occasion setter, we did not find the typical property of selective transfer of the modulatory function of R. This property, however, was very clearly present in the original experiment by De Houwer et al. (2005). One remaining difference between our studies is that the latter used two avoidance behaviors. In the next experiment, we therefore decided to use two avoidance behaviors and a negative stimulus occasion setter. This also allowed us to verify the original findings of De Houwer et al., who found that the modulatory function of an avoidance behavior is resistant to counterconditioning and transfers selectively to a relation that was previously modulated by another avoidance behavior. Furthermore, we increased the number of participants to improve the power of the statistical tests.

Method

Participants. Eighty-six participants took part. All were paid according to how successful they were in avoiding the US (on average, €5).

Stimuli, Materials, and Procedure. Only differences from the procedure used in Experiment 2 will be discussed. The experiment was run on a portable computer with a 15-in. screen and was controlled by an Inquisit 2.0 program (Millisecond Software, 2006). Whereas in the previous experiment the avoidance behavior consisted of pressing on the space bar, the two avoidance behaviors used in this experiment were presses on a green and a blue key. These keys corresponded to the keys "D" and "K" on an AZERTY keyboard. A green label was attached on the "D" key and a blue label was attached on the "K" key. A fourth warning signal was introduced: a pentagon, 2 cm wide and 2 cm high.

Whether the blue or the green key functioned as R1 or R2 was counterbalanced. In the first phase (see Table 3), participants received four A1+ trials, four A2+ trials, four B+ trials, two C+ trials, and two C− trials. In the second learning phase, there were four A1R1− trials, four A2R2− trials, four BT− trials, two C+ trials, and two C− trials. The A1R1− and A2R2− trials were identical to the AR− trials in Experiment 2, except that after the shape had disappeared, the message "the green key is available" or "the blue key is available" appeared in the upper part of the frame and remained there for 2,000 msec. If the available key was pressed during that time, a registration bar in the corresponding color of the key appeared on the screen for 1,000 msec as soon as the message in which the availability of a key was signalled had disappeared. No US was presented on these trials. The BT− trials were identical to the BT− trials of the previous experiment.

In a third learning phase, all previous trials were presented again and eight R1+ trials were added. These trials were almost identical to the R+ trials of the previous experiment, the only difference being that the message "press the [color of R1] key" appeared on the screen.

In the rating phase, the question concerning situations in which a warning signal and a response were present read as follows: "If you see the [name of shape] and you press the [color of key] key, how likely is it that the red X would be presented?" For situations in which no shape was presented and an avoidance response was present, the question read as follows: "If you see no shape and you press the [color of key] key, how likely is it that the red X would be presented?"

Table 3
Summary of the Design of Experiment 3 and Mean US Expectancies and Standard Deviations for the Rating Phase

Phase 1	Phase 2	Phase 3	Test Phase	M^{**}	SD^{**}
A1+	A1R1−*	A1+	A1?	76.60	29.97
A2+	A2R2−*	A2+	A2?	74.60	26.71
B+	BT−	B+	B?	62.78	26.90
C+	C+	C+	C?	62.59	25.43
C−	C−	C−	A1R1?	33.41	29.74
		A1R1−*	A2R1?	55.27	31.44
		A2R2−*	BR1?	46.48	28.21
		BT−	CR1?	51.30	28.75
		R1+	A1R2?	53.26	33.54
			A2R2?	32.71	32.07
			BR2?	46.62	30.28
			CR2?	48.06	30.85
			A1T?	40.52	30.93
			A2T?	40.34	32.40
			BT?	23.04	29.50
			CT?	38.06	31.13
			R1?	63.84	31.87
			R2?	36.01	29.78
			T?	24.03	30.32

*The US was absent only when participants pressed the appropriate key. **The mean US expectancy and standard deviation for the ratings are based on the data of all participants.

Results

Trained modulation. The means and standard deviations of all relevant indices can be found in Table 4. First of all, we calculated a trained modulation index for both avoidance behaviors (i.e., [([A1 − A1R1] + [A2 − A2R2])/2]). A one-sample *t* test indicated that this index was different from zero [$t(85) = 10.62, p < .001$]. When we looked at both avoidance behaviors separately, the modulation index for R1 (i.e., [A1 − A1R1]) was different from zero, as was the modulation index for R2 (i.e., [A2 − A2R2]) [$t(85) = 9.14, p < .001$, and $t(85) = 9.15, p < .001$, respectively]. These results indicated that R1 and R2 modulated responding to A1 and A2, respectively.

Second, we calculated a modulation index for T (i.e., [B − BT]). This index was significantly different from zero [$t(85) = 10.07, p < .001$], indicating that T modulated responding to B.

Resistance against counterconditioning. Because of the additional counterconditioning trials and a design with two avoidance behaviors, it was possible to calculate a counterconditioning index. In this index, we compared the modulatory power of R1, for which counterconditioning trials were presented, with the modulatory power of R2, for which counterconditioning trials were not presented (i.e., [(A2 − A2R2) − (A1 − A1R1)]). This index was not significantly different from zero [$t(85) = -0.27, p = .78$], indicating that there was no difference in modulation for R1 and for R2. The modulatory function of avoidance behavior R1 is thus resistant against counterconditioning. Counterconditioning did, however, influence responding to R1. A paired-samples *t* test indicated that US expectancy after R1 was significantly stronger than US expectancy after R2 [$t(85) = 6.00, p < .001$].

Selective transfer. Analogous to the previous experiments, the data of 28 participants who had a modulation index for T and a modulation index for R1 and R2 (i.e., [([A1 − A1R1] + [A2 − A2R2])/2]) below or equal to zero were removed from further analyses. All relevant transfer indices can be found in Table 4.

First, we investigated the extent to which the stimulus occasion setter T modulated responding to the warning signals A1 and A2 that were trained together with the avoidance behaviors. For this purpose, we calculated a transfer index for T with regard to responding to A1 and A2 (i.e., [([A1 − A1T] + [A2 − A2T])/2]). This index was different from zero [$t(57) = 8.79, p < .001$]. We also calculated a transfer index for the avoidance behaviors to capture the extent to which they modulated responding to the warning signal that was trained with the tone (i.e., [([B − BR1] + [B − BR2])/2]). Again, this index was different from zero [$t(57) = 4.32, p < .001$]. If we split up this transfer index for R1 and R2, both the index for R1 (i.e., [B − BR1]) and the index for R2 (i.e., [B − BR2]) were different from zero [$t(57) = 4.08, p < .001$, and $t(57) = 4.19, p < .001$, respectively].

We also investigated the transfer of the modulatory function of the tone and the avoidance behaviors with regard to the partially reinforced stimulus C. First, we calculated a transfer index for T (i.e., [C − CT]). This index was different from zero [$t(57) = 3.99, p < .001$]. We also

Table 4
Mean US Expectancies and Standard Deviations for the Indices of Experiment 3

	Index	*M*	*SD*
Trained modulation	([A1 − A1R1] + [A2 − A2R2])/2	42.55	37.16
	A1 − A1R1	43.20	43.83
	A2 − A2R2	41.89	42.48
	B − BT	39.74	36.60
Resistance against counterconditioning	(A2 − A2R2) − (A1 − A1R1)	−1.30	43.92
Transfer to other targets	([B − BR1] + [B − BR2])/2	19.71	34.73
	B − BR1	19.52	36.39
	B − BR2	19.91	36.18
	([A1 − A1T] + [A2 − A2T])/2	40.40	35.00
	([A2 − A2R1] + [A1 − A1R2])/2	27.60	31.91
	A2 − A2R1	25.76	37.72
	A1 − A1R2	29.45	37.83
Transfer to C	([C − CR1] + [C − CR2])/2	10.97	37.22
	C − CR1	8.67	40.41
	C − CR2	13.28	44.99
	C − CT	19.88	37.94
Selective transfer targets	([(B − BR1)/B] + [(B − BR2)/B])/2	0.17	0.62
	(B − BR1)/B	0.14	0.69
	(B − BR2)/B	0.19	0.61
	(A2 − A2R1)/A2	0.13	1.31
	(A1 − A1R2)/A1	0.33	0.46
	([(A1 − A1T)/A1] + [(A2 − A2T)/A2])/2	0.37	0.77
	([(A1 − A1R2)/A1] + [(A2 − A2R1)/A2])/2	0.23	0.73
Selective transfer C	([(C − CR1)/C] + [(C − CR2)/C])/2	−0.34	1.87
	(C − CR1)/C	−0.39	1.91
	(C − CR2)/C	−0.28	1.89
	(C − CT)/C	0.00	1.38

computed the transfer index for the avoidance behaviors (i.e., [([C − CR1] + [C − CR2])/2]). This index was different from zero [$t(57) = 2.24$, $p < .05$]. If we calculate the transfer index for R1 and R2 separately, the transfer index for R1 (i.e., [C − CR1]) was not different from zero [$t(57) = 1.63$, $p = .11$], whereas the transfer index for R2 (i.e., [C − CR2]) did differ from zero [$t(57) = 2.25$, $p < .05$].

For the analyses of selective transfer, we again took the proportion of modulation because the mean rating for C ($M = 59.19$, $SD = 25.83$) was lower than those for A1, A2, and B ($M = 75.68$, $SD = 16.82$) [$t(57) = -4.08$, $p < .001$]. We calculated a relative transfer index for T with regard to the A1–US and the A2–US relations (i.e., [([(A1 − A1T)/A1] + [(A2 − A2T)/A2])/2]) and a relative transfer index for T with regard to the C–US relation (i.e., [(C − CT)/C]). A *t* test indicated that these indices differed from each other [$t(57) = 1.99$, $p = .05$], showing selective transfer of the modulatory power of the stimulus occasion setter T. Next, we calculated a relative transfer index for the avoidance behaviors with regard to responding to B (i.e., [([(B − BR1)/B] + [(B − BR2)/B])/2]) and to C (i.e., [([(C − CR1)/C] + [(C − CR2)/C])/2]). These two indices were different [$t(57) = 2.01$, $p < .05$], indicating selective transfer of the modulatory power of the avoidance behaviors. When we repeated the analyses for each avoidance behavior separately, the modulatory function of R1 transferred significantly more to the B–US relation (i.e., [(B − BR1)/B]) than to the C–US relation (i.e., [(C − CR1)/C]) [$t(57) = 2.05$, $p < .05$], whereas for R2 the difference was only marginally significant (i.e., [(B − BR2)/B], [(C − CR2)/C]) [$t(57) = 1.91$, $p = .06$].

As in the previous experiments, we also tested selective transfer by comparing absolute difference scores. These results indicated that modulation by T and by R1 transferred selectively [$t(57) = 4.30$, $p < .001$, and $t(57) = 1.97$, $p = .05$, respectively]. Modulation by R2 did not transfer selectively [$t(57) = 1.05$, $p = .30$]. As in the previous experiments, it is important to keep in mind that the baseline ratings for A1, A2, and B were significantly different from the baseline ratings of C.

Finally, we also examined whether the modulatory function of an avoidance behavior transfers selectively to a relation previously modulated by another avoidance behavior. We first used transfer to C as a point of reference. A *t* test showed that the relative degree to which R1 and R2 modulated responding to A2 and A1, respectively (i.e., [([(A2 − A2R1)/A2] + [(A1 − A1R2)/A1])/2]), differed from the relative degree to which R1 and R2 modulated responding to C (i.e., [([(C − CR1)/C] + [(C − CR2)/C])/2]) [$t(57) = -2.25$, $p < .05$]. The modulatory function of R1 tended to transfer more to the A2–US relation ([(A2 − A2AR1)/A2]) than to the C–US relation (i.e., [(C − CR1)/C]) [$t(57) = -1.79$, $p = .08$]. The modulatory function of R2 transferred significantly more to the A1–US relation ([(A1 − A1R2)/A1]) than to the C–US relation ([(C − CR2)/C]) [$t(57) = -2.56$, $p < .05$]. Second, we used transfer to B as the point of reference. This allowed us to examine whether the modulatory function of an avoidance behavior transfers more to a relation previously modulated by another avoidance behavior than to a relation previously modulated by a stimulus occasion setter. When we compared the transfer index of R1 and R2 with the A2–US and the A1–US relations (i.e., [([A2 − A2R1] + [A1 − A1R2])/2]) and the transfer index of R1 and R2 with the B–US relation (i.e., [([B − BR1] + [B − BR2])/2]), these indices were significantly different [$t(57) = -2.35$, $p < .05$]. The transfer indices of R1 to the A2–US relation (i.e., [A2 − A2R1]) and to the B–US relation (i.e., [B − BR1]) were not significantly different [$t(57) = -1.28$, $p = .20$], whereas the transfer indices of R2 to the A1–US relation (i.e., [A1 − A1R2]) and to the B–US relation (i.e., [B − BR2]) did differ [$t(57) = -2.37$, $p < .05$].

Discussion

As expected, the results displayed trained modulation for the two avoidance behaviors and the negative stimulus occasion setter. Furthermore, we found evidence that the modulatory function of an avoidance behavior is resistant against counterconditioning. To test whether the function of a negative stimulus occasion setter and an avoidance behavior were interchangeable, it was important to investigate selective transfer. As in the previous experiments, the modulatory powers of the tone transferred selectively to the warning signal–US relations previously modulated by the avoidance behaviors. For the first time, the results also indicated selective transfer of the modulatory function of the avoidance behaviors toward the relation that was previously modulated by the tone. Furthermore, in line with De Houwer et al. (2005), we found evidence for selective transfer of both avoidance responses to relations that were previously modulated by the other avoidance response. This was true both when modulation of the C–US relation was taken as a point of reference (for both R1 and R2) and when transfer to the B–US relation was taken as a point of reference (but only for R2). The reported results give strong support to the hypothesis that an avoidance behavior can act as a negative occasion setter.

GENERAL DISCUSSION

In this article, we examined whether the function of a negative stimulus occasion setter and an avoidance behavior are interchangeable. We therefore investigated whether the modulatory powers of a negative stimulus occasion setter transfer selectively to a relation that was formerly modulated by an avoidance behavior and whether the modulatory powers of an avoidance behavior transfer selectively to a relation previously modulated by a negative stimulus occasion setter.

In three experiments, we observed that the modulatory powers of the negative stimulus occasion setter did transfer selectively to stimuli whose relation with the US was previously modulated by the avoidance behavior. This shows that participants recognized that the negative stimulus occasion setter and the avoidance behavior are equivalent, in that they both signal when a certain warning signal–US relation will be present. Hence, it provides strong evidence for the claim that an avoidance behavior can take the function of a negative occasion setter.

We also observed that the avoidance behavior modulated responding to the warning signal–US relation that was previously involved in training with the stimulus occasion setter. In Experiment 3, this transfer of modulation was stronger than that for a warning signal whose relation with the US was partially reinforced. This finding provides additional evidence for the hypothesis that an avoidance behavior can have the function of a negative occasion setter. It should be noted, however, that selective transfer of the modulatory function of an avoidance behavior was observed only in Experiment 3. There may be several reasons why selective transfer of the avoidance behavior was present in this experiment. First of all, more participants took part in this experiment, resulting in a higher statistical power of the tests. A second possible reason is the introduction of a second avoidance response. We introduced this change in the design to make the study more comparable with the study of De Houwer et al. (2005), who also found selective transfer of the modulatory power of avoidance behaviors. It is unclear, however, why this procedural change would enhance the likelihood of selective transfer. One could argue that with two responses, participants could observe that R1 modulated the A1–US relation in the same way as R2 modulated the A2–US relation. This might have drawn attention to the equivalence of these two relations and highlighted the fact that these relations were different from the other warning signal–US relations, thus resulting in more selective transfer. This account is, however, speculative, and remains to be tested in future research. Nevertheless, the fact remains that the selective transfer effect appears to be small and present only for one avoidance behavior in one experiment. Hence, future research is needed before strong conclusions can be drawn with regard to whether modulation by an avoidance behavior transfers selectively to relations that have been modulated by a stimulus occasion setter.

The present results extend those of De Houwer et al. (2005) in several ways. First, they provide a new type of evidence for the hypothesis that an avoidance behavior can function as an occasion setter. Second, the evidence reported by De Houwer et al. was obtained in a situation where R+ trials were presented. One could argue that in those studies avoidance behavior functioned as an occasion setter only, because the counterconditioning prevented the avoidance behavior from becoming a conditioned inhibitor. In Experiment 1 of the present article, we found evidence for the occasion-setting hypothesis, even when R+ counterconditioning trials were absent. In fact, the evidence obtained in Experiment 1 was as clear as that obtained in Experiment 2, where counterconditioning trials were presented. We can thus conclude that an avoidance behavior can take the function of an occasion setter, even in situations where the avoidance behavior could have become a conditioned inhibitor.

The reported results cannot be explained by other theories of avoidance learning. The two-factor theory of Mowrer (1947) assumes that an avoidance response is elicited by the warning signal as a result of stimulus–response associations. It is assumed that, as the result of the pairings of the warning signal and the US, the warning signal will start to elicit a conditioned fear response. The avoidance response is then reinforced by a reduction in conditioned fear. Because the US plays a role only in inducing conditioned fear, the two-factor theory makes no predictions about whether an avoidance behavior modulates the degree to which a US is expected after the presentation of certain stimuli, whether this modulation is resistant against counterconditioning, whether the modulation by a stimulus occasion setter transfers selectively to relations previously modulated by an avoidance behavior, and whether modulation by an avoidance behavior transfers selectively to relations previously modulated by a stimulus occasion setter.

In other versions of the two-factor theory, US expectancy is important. Gray (1987), for instance, assumed that stimuli that accompany the avoidance response become safety signals because they signal the absence of an expected US. These safety signals are supposed to reinforce the avoidance response. As in the original two-factor model, the avoidance behavior is simply elicited by the warning signal and is not assumed to depend on or modulate the expectancy of the US. Hence, Gray's model cannot account for the findings addressed in this article.

According to the theory of Seligman and Johnston (1973), avoidance behavior is emitted because of knowledge about how it affects the probability of the US. It is assumed that participants expect the absence of a US after the performance of an avoidance response and expect the presence of the US after not performing the avoidance response. Nevertheless, it is not clear how the theory would explain resistance of the modulatory function of the avoidance responses to counterconditioning, or how it transfers selectively. If one assumes that the expectancies about the R–US relation are context dependent (i.e., the warning signal functions as a context), one could explain why trained modulation is not influenced by counterconditioning trials given in another context (i.e., without a warning signal). But if expectancies are so context specific, no transfer of modulation, least of all selective transfer, should occur at all.

Another theory of avoidance learning was recently developed by Lovibond (2006). He stated that participants expect a particular US after the presentation of a particular warning signal and expect the absence of a particular US after the performance of a particular avoidance behavior. This theory cannot explain why the modulatory function of an avoidance behavior is resistant against counterconditioning, because additional R+ trials should contradict the expectancy that the US will be absent after the performance of the avoidance behavior. Moreover, the model cannot explain why transfer of modulation would be stronger for relations that were previously modulated.

Although our results support the idea that avoidance behavior is functionally similar to a stimulus occasion setter, it is not clear what processes underlie the occasion-setting function of a behavioral or stimulus occasion setter. It is generally accepted that the functional properties of occasion setting are not due to a direct inhibitory association between the representation of the occasion setter and the representation of the US (Swartzentruber, 1998). The assumption of such an inhibitory association could allow one to explain modulation, because the presence of the occasion setter would lower the activation of the US representation and thus US expectancy. However, counterconditioning trials should weaken the inhibitory association between the representations of the occasion setter and the US, and should thus reduce the modulatory power of the occasion setter. Moreover, it is not clear why the modulatory power of the occasion setter should transfer more to some relations than to others. The direct inhibitory association between the occasion setter and US representations should reduce the activation of the US representation to an equal amount, whether or not the association between the warning signal and the US representation is itself modulated by another occasion setter. Hence, by showing that avoidance behavior can have the functional properties of an occasion setter, we raise doubts about the hypothesis that avoidance behavior is always driven by a direct inhibitory association between the representations of the behavior and the US.

What processes underlie the ability of an avoidance behavior to function as an occasion setter? At present, there are two dominant process accounts of occasion setting. According to the modulation account (Holland, 1983; Ross & Holland, 1981), the occasion setter modulates the activity of an excitatory association between the representations of the warning signal (or CS) and the US. It does so independently of its own association with the US. A second popular account is couched in terms of Pearce's configural model of learning (e.g., Pearce, 1987, 1994). This account entails that the warning signal and occasion setter are represented as one configural stimulus. This configural representation may enter into an inhibitory association with the US. Given the right parameters of generalization between representations, the model can explain how the unique functional properties of occasion setting come about. One could argue that, in the case of avoidance behavior, it is unlikely that the behavior and the warning signal are somehow coded in a single configural representation. As such, our data could be seen as indirect support for a modulation account of occasion setting. Nevertheless, it is beyond the scope of the present article to solve the long-standing question of what processes underlie the functional properties of occasion setting.

The reported results also provide a second contribution to the literature on occasion setting. Until now, it has generally been assumed that occasion setting occurs only when the occasion setter is presented before the target. This is based on studies showing stronger occasion setting under those conditions than under conditions where the occasion setter and the target were presented simultaneously (Baeyens et al., 2004; Holland, 1984; Swartzentruber, 1995). In our experiments, we showed not only that an avoidance response, performed after the warning signal, can function as a negative occasion setter, but also that a tone presented after the target can also so function. The fact that we did find evidence for occasion setting under these conditions could have been related to the fact that all warning signals (visually presented forms) were of a different modality from the occasion setter (the auditory tone or the avoidance behavior). This could have encouraged participants to consider the possibility that the occasion setter had a different function than the targets did. Also, participants first learned that warning signals were followed by the US. Only afterward did they learn that the targets were not followed by the US when an avoidance behavior or stimulus occasion setter was present. This could have led participants to believe that the avoidance behavior and stimulus occasion setter signalled when a previously learned warning signal–US relation was not valid. It would be interesting to examine these hypotheses in future studies.

Finally, we want to draw attention to a number of limitations and problems in the reported studies. First, only the data of participants who showed trained modulation for both the avoidance response as the stimulus occasion setter were included in the analyses designed to test whether modulation transferred selectively. Although this selection is reasonable, given that modulation can transfer selectively only when it is present in the first place, it led to the removal of a substantial part of the data. The fact that results were consistent over three consecutive experiments does, however, provide assurance that the reported effects are genuine and reliable. The consistency of the results also reduces doubts about possible Type I errors in the many statistical tests that we needed to conduct. On the other hand, it would be good to reduce the number of participants that need to be removed from the analyses. One way would be to adopt a learning criterion, so that participants can advance only to the next phase of the learning phase after they correctly reproduce the events of the previous phase (see Declercq, De Houwer, & Baeyens, in press). Another potential problem with the reported studies was the use of a partially reinforced stimulus C that was added to investigate selective transfer. The baseline ratings for C were always different from the other stimuli. This made the analyses of selective transfer more complex. To circumvent this problem, we made use of ratio scores. Nevertheless, these ratio scores entailed psychometric problems. Using a 100% reinforced transfer target might circumvent these problems in future research.

Despite these limitations, the reported studies advance our understanding of avoidance learning and occasion setting by showing that the two phenomena are interrelated in important ways. Although we do not exclude the possibility that avoidance behavior does not always have the properties of an occasion setter, our results do confirm that one should take seriously the possibility that avoidance behavior is emitted because it modulates warning signal–US relations. This insight is not only theoretically relevant but also has practical implications. Most importantly, attempts to change avoidance behavior that has the function of an occasion setter should focus not on the direct relation between the avoidance behavior and the US (i.e., punishment or counterconditioning of the avoidance behavior; see Gwinn, 1949, and Solomon, Kamin, & Wynne, 1953). Instead, interventions should focus on assumptions about whether the avoidance behavior can modulate particular warning signal–US relations.

AUTHOR NOTE

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