Tom Beckers · Jan De Houwer · Paul Eelen

Automatic integration of non-perceptual action effect features: the case of the associative affective Simon effect

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Abstract In the first phase of Experiment 1, participants were instructed to move a response key up or down in response to a go signal. One of both responses was consistently followed by an aversive stimulus, whereas the other response was never followed by the aversive stimulus. In a subsequent test phase, the same responses had to be emitted according to the grammatical category (noun or adjective) of positive and negative target words. Results showed that the level of affective correspondence between the task-irrelevant positive or negative connotation of the target and the motivational significance of the effect of the correct response influenced performance. The results of Experiment 2 replicated those of Experiment 1, using alternating target-response assignment. These findings point to the integration of affective action effect feature codes in the cognitive representation of actions.

Introduction

Perception and action are intimately coupled and interact abundantly. The recently proposed Theory of Event Coding (Hommel, Müsseler, Aschersleben, & Prinz, *in press*) argues that one of the reasons for this is that perception and action (as well as attention and intention) share a common representational space (Brewer, 1993; Prinz, 1990). In this coding space, perceptual as well as action concepts are distributed collections of more or less abstract (distal) feature codes. These concepts represent the integrated features of the percept

impinging on a perceiver's senses (perceptual concept), or the integrated perceptual feedback an actor receives contingent upon the execution of a particular action (action concept). From a functional point of view, there is thus no difference between perceptual and action concepts: they all represent perceptual input by means of an integrated set of feature codes. Importantly, one and the same feature code can be part of various perceptual and/or action concepts. Tantamount to the notion that actions are represented in terms of their perceptual feedback effects is the idea that activating one or more feature codes representing an action's effects primes the execution of that action, at least to a certain degree. This idea can be regarded as a reformulation of the ideomotor principle as formulated by James (1890; see also Greenwald, 1970).

The common coding hypothesis has been invoked to explain the emergence of stimulus-response compatibility effects such as the Simon effect. In a typical Simon task, coloured target stimuli are presented and participants are to react to the colour of the targets by pressing either a left or a right response key. Importantly, targets are either presented to the left or to the right of fixation. One typically observes faster and/or more accurate performance when there is spatial correspondence between the target and the correct response than when there is no such correspondence (for reviews see Lu & Proctor, 1995; Simon, 1990). From a common coding framework, such a result can be readily explained. Perceiving a target stimulus relies on the activation of the feature codes that make up the target's cognitive representation. One of these is a code representing the spatial location of the target, say *left*. As a result, all concepts incorporating this code will be partially activated. The *left* code is also part of the representation of one of both responses, so that perceiving a target necessarily implies partial activation of the spatially corresponding response. If the primed response is the response that has to be emitted, response selection is facilitated; if the primed response is incorrect, response selection is hampered due to a conflict between primed response and correct response

T. Beckers (✉) · P. Eelen
Department of Psychology, Katholieke Universiteit Leuven,
Tiensestraat 102, 3000 Leuven, Belgium
E-mail: tom.beckers@psy.kuleuven.ac.be
Tel.: +32-16-325953
Fax: +32-16-325924

J. De Houwer
University of Ghent, Ghent, Belgium

(Hommel, 1997). Note that stimulus-response compatibility effects like the Simon effect thus critically depend on the stimulus set and the response set sharing one or more dimensions on which stimuli and responses vary, in this case spatial location (a condition termed *dimensional overlap*; Kornblum, Hasbroucq, & Osman, 1990).

A corollary to the notion that actions are represented in terms of their effects, is the idea that if the effects that an action produces change, the cognitive representation of that action ought to change accordingly (Hommel, 1998). As a result, merely perceiving a stimulus that shares one or more features with the novel, only recently acquired effect of an action should be sufficient to facilitate the selection of that action, as well as to hinder the selection of incompatible actions (due to response conflict). This prediction has recently been confirmed (Elsner & Hommel, 2001; Hommel, 1996). In a seminal experiment (Hommel, 1996, Experiment 2), participants were instructed to react to the colour of a target stimulus by pressing a response key once or twice. During the learning phase, targets always appeared at screen centre. In the test phase, targets appeared either to the left or to the right of screen centre. Throughout the experiment, one of both responses always yielded a tone to the left, whereas the other response always yielded a tone to the right. This set-up is quite similar to a typical Simon task: participants are to respond to the colour of target stimuli that are presented either to the left or to the right. A crucial difference with the standard Simon task, however, is that the responses that participants have to emit are initially neutral with respect to spatial location (i.e. press a key once or twice). As such, there is no dimensional overlap between the stimulus set and the response set. Dimensional overlap arises only to the extent that the spatial action effect feature codes get included in the respective cognitive representations of the actions that produce them. Only then is it possible for the target stimulus location to selectively facilitate the selection of one response above the other. Several experiments showed that compatibility effects of this nature can indeed be found. For instance, if pressing a key once leads to a tone to the left, this response is selected more quickly if the eliciting stimulus is presented on the left side of the screen. Results such as these provide evidence for the (supposedly automatic) integration of action effect feature codes in the cognitive representations of the actions that produce them. This lends support to the idea that actions are represented in terms of their perceived effects, and thus to the plausibility of common coding of perception and action in the cognitive system on the one hand, and to the role of ideomotor processes in action control on the other hand.

In action control, perceptual feedback is of extreme importance. It allows one to correct actions during execution, and it provides action with the possibility to adapt to constantly changing physical circumstances. It is thus not surprising that the cognitive system would attach quite some importance to the perceptual changes

that actions bring forth, and that it would represent actions in terms of the perceivable effects they produce. Accordingly, the cognitive reformulation of the ideomotor principle and its adoption in a common-coding framework that states that actions are represented in terms of their perceived effects has recently triggered a host of research revealing the impact of perceptual action effect code integration on human performance (e.g. Elsner & Hommel, 2001; Hazeltine, in press; Hoffmann, Sebold, & Stöcker, 2001; Kerzel, Bekkering, Wohlshläger, & Prinz, 2000; Kunde, 2001; Kunde, Hoffmann & Zellmann, 2002; Zießler & Nattkemper, in press. However, it may be contended that not only perceptual feedback is important for action control. Features of an action's effects that are not directly observable, notably the affective evaluation elicited by and attached to the effects that an action produces, are arguably at least as crucial as the perceivable aspects of an action's effects¹. Apart from monitoring the directly perceivable physical changes that an action produces, it is therefore probably beneficial to also keep track of the emotional significance of (the effects of) an action by integrating not only perceptual feature codes, but also valence codes in an action's cognitive representation. Nevertheless, up until now all research in the domain of stimulus-response compatibility has focused exclusively on the impact of perceptual (most often spatial) action effect codes, with only one exception (Van der Goten, Lammertyn, De Vooght, & Hommel; The functional basis of backward compatibility effects: selecting emotional actions primes the perception of emotional words; submitted for publication). We will now describe this last study in more detail because it may at first sight seem relevant to the integration of affective information in the cognitive representation of actions.

In a first experiment (Experiment 2, Van der Goten et al., submitted.), participants performed a double task. Task 1 required them to press a central response key once or twice (R1) according to the emotional valence of a target word (S1). Task 2 required them to press a left or a right response key (R2) according to the colour of a target square (S2). S1 and S2 were presented in rapid succession, and participants were instructed to perform R1 before R2. Importantly, one of both R2 responses always yielded a *smiley* (a smiling face, i.e. a positive action effect), whereas the other response always yielded a *grumpy* (a cross-looking face, i.e. a negative action effect; we will refer to the effect of R2 as E2). In a second experiment (Experiment 3, Van der Goten et al., submitted), participants were instructed to respond according to the letter case of the target words S1 rather than according to their emotional valence. In both experiments, correspondence between E2 (a smiley or

¹By directly observable action effect features, we mean the objective, physical properties of an action's effects. In contrast, the actor's affective evaluation of an action's effects may well be perceived by the actor, but is not a property of the effects themselves (see also General discussion).

frowny face) and S1 (a positive or negative word) yielded faster R1 reaction times (RTs) than non-correspondence between the effect of R2 and S1. The authors take this to indicate that the preparation of R2 led to the activation of its effect (E2), and that activation of E2 facilitated the processing of the corresponding S1 and/or hampered the processing of the non-corresponding S1. However, stated as such, their results only imply that E2 became associated to R2 (so that activation of R2 lead to the activation of E2), rather than implying that E2 became integrated in R2 (which signifies at least a bi-directional association between R2 and E2, so that R2 activation does not only lead to E2 activation, but E2 activation also leads to R2 activation, as is needed for ideo-motor control). Furthermore, the results of Van der Goten et al. (submitted) may even be explained without any reference to action-effect learning at all. Indeed, to the extent that participants responded accurately to S2, the contingency between R2 and E2 brought along a concomitant contingency between S2 and E2. Therefore, participants may well have acquired S2-E2 associations (linking colour with valence), rather than R2-E2 associations. Because of the rapid succession of S1 and S2, S2 may then have activated E2 before execution of R1 (without any involvement of R2 preparation). The alleged backward R-S (or actually E-S) compatibility effect then boils down to a simple S-S (or actually E-S) compatibility effect (with E2, activated via S2, priming the processing of S1). Summarising, the results of Van der Goten et al. (submitted) do not speak to the degree to which activating affective action effect representations leads to the activation of the actions that produce them (the ideo-motor principle), nor do they necessarily inform us about the common coding of perception and action and the role of valence codes in this common coding (it be noted that this topic was not the primary concern of their study either). However, their results do suggest that learning about affective event features can take place, and that it can influence dual task performance.

Solid evidence for integration of affective action effect codes in action representations (i.e. evidence showing that actions can be primed by presenting stimuli that have affective rather than physical correspondence with that action's effects) is thus not yet available. Moreover, and despite the seemingly evident nature of the idea that affective information is important for action control, integration of affective action effect features is not (or at least not explicitly) predicted by a common coding framework such as the Theory of Event Coding (Hommel et al., *in press*). Indeed, even though feature codes can refer to distal dimensions as complex as "sit-on-ability" (Gibson, 1979), they seem only to concern perceivable action effect feature codes, referring to physical properties of the action-produced perceptual feedback. As such, action effect feature code integration is expected to occur for observables, but not (or not necessarily) for semantics (e.g. the affective connotation of an action's effects) or second-order feedback (e.g. the

affective reaction elicited by an action's effects; see General Discussion).

We decided to tackle the question of whether affective action effect features get included in the representation of the actions that produce them (as is the case for perceptual action effect features) empirically. To this end, we set up an affective variant of the associative Simon task developed by Hommel (1996; for the basic affective Simon paradigm, see De Houwer, Crombez, Baeyens, & Hermans, 2001; De Houwer & Eelen, 1998). In the training phase, participants were instructed to move a response key up or down in reaction to a go-signal. One of both responses was consistently followed by an aversive electrocutaneous stimulus (an action effect with a negative valence); the other response was never followed by the aversive stimulus (in this context an action effect with a positive valence: Dinsmoor, 1977; Rescorla, 1968)² During the test phase, words with a positive or negative connotation were presented instead of go-signals, and participants were to move the response key up or down according to the grammatical category (noun or adjective) of the words. Responses yielded the same effects as in the training phase. Dimensional overlap between targets and responses, resulting in an affective compatibility effect, could only arise to the extent that the responses' representations would come to incorporate affective action effect feature codes.

Experiment 1

Method

Participants

Twenty undergraduate students at the Katholieke Universiteit Leuven participated for partial fulfilment of course requirements. All participants had normal or corrected-to normal vision, were native Dutch speakers, and were naive as to the purpose of the experiment.

Stimuli

For the test phase, 30 words with a clearly positive valence and 30 words with a clearly negative valence (experimental targets; 15 nouns and 15 adjectives each), as well as 8 neutral words (warming-up targets; 4 nouns and 4 adjectives) were selected from a list with affective ratings for Dutch words (Hermans & De Houwer, 1994)³.

²One can debate whether from the viewpoint of the participants the action-effect is the electrocutaneous stimulus or the sensations (pain) that the stimulus causes, or, stated differently, to what extent the pain produced by the electrocutaneous stimulus is an objective and directly given action effect feature. However, the fact that these sensations are evaluated as negative (and their absence as positive) by the participants is not an objective, physical action effect feature at any rate.

³The verbal stimuli included words such as *wens* (wish), *vriend* (friend), *schandaal* (scandal), *stank* (stench), *zuiver* (pure), *gelukkig* (happy), *vulgar* (vulgar), *vervelend* (annoying).

Apparatus

Stimulus presentation and response registration were controlled by a custom made Turbo Pascal program and timing routine (Bovens & Brysbaert, 1990). The program was implemented on an IBM compatible P160 PC with a 15-inch SVGA screen. The index finger of the dominant hand was attached to a response button that could be moved upward or downward on a vertical plane, and through which an electrocutaneous stimulus could be presented. The intensity of the electrocutaneous stimulus could be individually adjusted by means of an adapter.

Procedure

Before the beginning of the actual experiment, a cover story was presented to the participants, stating that they were taking part in a study about the effects of stress on the performance in RT tasks. The intensity of the electrocutaneous stimulus was then set by gradual increase in a work-up procedure, at a level that the participant perceived as clearly unpleasant and demanding some effort to tolerate, but not painful.

The first phase of the experiment was a free choice training phase. After an intertrial interval of 500 ms, each trial started with a fixation cross that stayed on screen for 500 ms, followed by a blank screen for 500 ms. Then a go signal (an asterisk at screen centre) was presented. Upon presentation of the go signal, participants were free to move the response key upward or downward, but they were informed that the training phase would continue until each of both responses had been emitted at least 60 times (so training proceeded for at least 120 trials). Maximum RT was 3,000 ms. One of both responses always yielded an electrocutaneous stimulus of individually adjusted intensity (response-effect assignment was counterbalanced across participants). After each trial, feedback on how often each response had been emitted up to that point was presented for 1,000 ms. If no response was emitted within 3,000 ms, an error message was displayed for 750 ms.

The test phase consisted of 68 trials, divided in two blocks of 34 trials separated by a user-terminated break. After an intertrial interval of 1,500 ms, each trial started with a fixation cross that stayed on screen for 500 ms, followed by a blank screen for 500 ms. Then a target word was presented, which stayed on screen until a response was given or 3,000 ms elapsed. Warming-up targets were presented on the first four trials and experimental targets on the remaining 30 trials of a sub-block. Each of the 60 experimental targets was presented once, in a random order, with the restriction that no more than four words of the same grammatical category were presented in a row. Half of the participants were instructed to react with a downward response to nouns and an upward response to adjectives, for the other half of the participants the target-response assignment was reversed (counterbalanced with response-effect assignment). Responses yielded the same effects as in the training phase. If no response was emitted within 3,000 ms after target onset or an incorrect response was emitted, an error message was displayed for 750 ms.

Results and discussion

For all participants, mean RTs and percentages of errors (PEs) were calculated for each of the four combinations of target valence (positive or negative) and response type (required response associated with a positively or with a negatively evaluated effect) separately (over target words). Trials on which reaction times were below 150 ms (anticipations) or above 1,500 ms (omissions) were discarded from the analyses (2.75% of the data). RTs and PEs were each subjected to a 2×2 analysis of variance (ANOVA), with target valence (positive,

negative) and response type (positive, negative) as within-subjects variables. Additionally, average RTs and PEs were calculated for all target words, for each response type separately (over participants). These means were also subjected to a 2×2 ANOVA, with target valence (positive, negative) as a between-targets variable and response type (positive, negative) as a within-targets variable. The significance level was set at $\alpha = 0.05$.

As expected, an ANOVA on the RTs revealed a significant interaction between target valence and response type, $F_1(1, 19) = 4.93$, $MSE = 3,640.40$. Responses that were consistently followed by a positive effect were emitted faster in response to positive targets ($M = 700.13$ ms, $SD = 117.50$) than to negative targets ($M = 748.36$, $SD = 127.26$), while responses that were consistently followed by a negative effect were emitted faster in response to negative targets ($M = 740.46$, $SD = 142.99$) than to positive targets ($M = 752.12$, $SD = 136.71$). The interaction between target valence and response type was also significant when means calculated over participants were subjected to an ANOVA over targets, $F_2(1, 58) = 5.73$, $MSE = 4,016.27$. This analysis also revealed a significant main effect of response type, $F_2(1, 58) = 5.43$, $MSE = 4,016.27$, reflecting a general tendency for responses yielding a negative effect to be performed somewhat slower ($M = 747.26$ ms, $SD = 91.72$) than responses yielding a positive effect ($M = 720.30$ ms, $SD = 82.84$). All other RT effects, as well as all PE effects, were non-significant (largest $F_1 = 3.32$, largest $F_2 = 1.83$).

Correspondence between the irrelevant affective connotation of a target word and the affective valence of the effect produced by the required response resulted in significantly faster performance than non-correspondence. This indicates that affective action effect features can become part of the cognitive representation of the actions that produce them, even when these action effects are irrelevant for the task at hand, and that affective action effect feature codes can subsequently influence action generation. Also, responses yielding unfavourable effects were emitted slower than responses yielding favourable effects. This may reflect a general conditioning effect, whereby participants become more hesitant and thus more slowly to emit punished actions compared to unpunished actions.

Experiment 2

Associative Simon effects are taken to indicate the integration of action effect feature codes in cognitive action representations. However, an alternative account for some of the results obtained in previous research is feasible. In many experiments there is a confounding between response-effect contingency and target-effect contingency, because participants are to respond according to some relevant feature of targets that are presented to them. For instance, in the seminal experiment by Hommel (1996, Experiment 2), participants

were to react according to the colour of the targets by pressing a key once or twice, which yielded a left or a right tone. Assume participants thereby learned to associate one colour with a left effect and the other colour with a right effect, instead of associating one response with a left effect and the other response with a right effect. Presenting targets either to the left or to the right of fixation would then yield differences in internal stimulus congruity (depending on whether the target's location matched the spatial code associated with the target's colour or not). To the extent that participants are faster in processing and reacting to internally congruous targets than to internally incongruous ones, the emergence of an associative Simon effect could then be explained without any reference to the integration of action effect codes in the cognitive representations of the actions that produce them at all (see Hasbroucq & Guiard, 1991, for a somewhat similar account of the original Simon effect).

Even though such an argument seems unlikely to provide a full account for all previous findings (and has been shown not to be able to fully explain the original Simon effect: e.g. O'Leary, Barber, & Simon, 1994; Zhang, 2000), Experiment 1 included a safeguard against this alternative explanation for the emerging affective compatibility effect, by ruling out all opportunity for target (category)-effect learning in the training phase. Indeed, no targets were presented in the training phase at all; this way, participants could not attribute the effects that their responses yielded to a target feature. There is, however, another way to prevent participants from acquiring target-effect relations. In the present experiment, target words were presented from the beginning of the training phase, and participants were instructed to react to the grammatical category of the targets by moving the response key up or down. Again, one response always resulted in an electrocutaneous effect stimulus, whereas the other response was never followed by the aversive stimulus. However, in the course of the training phase as well as the test phase, target-response assignment was regularly switched (i.e. after every 45 trials in the training phase, and 44 trials in the test phase, target-response assignment was reversed). This way, the consistent response-effect contingency was not accompanied by a consistent target category-effect contingency, so that participants could not but attribute the effects to the responses.

Introducing targets from the beginning of training on allowed us to implement an additional manipulation aimed at increasing the magnitude of the affective compatibility effect. In Experiment 1, we showed that the affective meaning of a target word can influence the speed of selecting a response to the grammatical category of the target, even though the affective meaning of the target was irrelevant and could be neglected by the participants. This does not only point to the integration of affective action effect features and their role in action control, it also speaks to the automatic nature of affective processing (e.g. Fazio, 2001; Hermans, De Houwer, & Eelen, 2001). Recently it has been claimed that spatial

information processing, even though highly automatic in nature too, can be influenced by strategic factors (e.g. Ridderinkhof, *in press*; Proctor & Vu, *in press*). The spatial Simon effect for instance, although crucially dependent on the automatic processing of task-irrelevant target location, can be greatly enhanced by rendering target location relevant on interspersed trials, that is, by including trials on which participants are instructed to respond according to the position of the target rather than to its colour (Ridderinkhof, *in press*). The issue of strategic influences on automatic processing arguably applies to affective information processing as well. Therefore, in the present experiment, we added trials on which participants were to react to the affective connotation (positive or negative) of the targets rather than to their grammatical category (noun or adjective), hoping to increase the size of the predicted affective compatibility effect.

Method

Participants

Twelve undergraduate students at the Katholieke Universiteit Leuven participated for partial fulfilment of course requirements. They conformed to the same criteria as for Experiment 1, in which they had not participated.

Stimuli and apparatus

The same stimuli and apparatus were used as for Experiment 1, albeit that now an IBM-compatible 386 PC with a 15-inch VGA screen was used. Verbal responses were emitted in a computer microphone that was not connected to the computer (unbeknownst to the participants).

Procedure

Before the beginning of the actual experiment, the same cover story was related to the participants as in Experiment 1, and the intensity of the electrocutaneous stimulus was adjusted to a level that the participant perceived as clearly unpleasant and demanding some effort to tolerate, but not painful.

The experiment started with a training phase consisting of 180 trials. Each trial started with a fixation cross, presented for 500 ms, followed by a blank screen for 500 ms. Then a target was presented. Targets were presented as white words; 300 ms after onset they turned either yellow or blue. If a target turned yellow (valence irrelevant trials or VI-trials), participants were to react to the grammatical category of the target by moving the response key up or down (cf. test phase of Experiment 1). One of both responses consistently yielded an electrocutaneous stimulus, whereas the other response never yielded an electrocutaneous stimulus (response-effect assignment was counterbalanced across participants). The target stayed on screen until a response was emitted or 3,000 ms elapsed. If no response was emitted within 3,000 ms, or if an incorrect response was emitted, an error message was displayed for 750 ms. If a target turned blue (valence relevant trials or VR-trials), participants were to evaluate the targets out loud as either good ("positive") or bad ("negative"). Upon evaluation, the experimenter pressed a key and the target disappeared. Each target word was presented twice in yellow and once in blue in the course of the training phase, so that the training phase counted 120 VI-trials and 60 VR-trials. Targets were presented in random order, apart from the following restrictions. No more than four VR-trials

were presented in a row, no more than six targets of the same grammatical category were presented in a row, and the same target was never presented on two consecutive trials. A break was provided after every 45 trials, at which moment target-response assignment for the VI-trials was switched: if a participant had been moving the response key up in reaction to nouns and down in reaction to adjectives, (s)he was now instructed to move the response key down in reaction to nouns and up in reaction to adjectives, and vice versa. Response-effect assignment was kept consistent throughout the training phase.

The test phase consisted of 80 test trials (60 VI-trials and 20 VR-trials) and 8 warming-up trials (VI-trials with neutral targets). Each target was presented once in yellow (VI-trials); for the VR-trials, 20 targets were randomly selected from the set of 60 targets. The test phase started with the same initial target-response assignment as the training phase had started with; after 4 warming-up trials and 40 test trials, a break was provided and target-response assignment was switched, after which the remaining warming-up trials and test trials were presented. No more than four VR-trials were presented in a row, and the same target was never presented on two consecutive trials. Response-effect assignment was the same as in the training phase. Note that there was no apparent difference between the training phase and the test phase for the participants.

Results and discussion

Performance on VI-trials was analysed as for Experiment 1. Anticipations and omissions accounted for 2.92% of the data.

An ANOVA on the RTs again revealed a significant interaction between target valence and response type, $F_1(1, 11) = 8.70$, $MSE = 3,003.94$. Responses yielding a positive effect were emitted faster to positive targets ($M = 533.62$ ms, $SD = 153.20$) than to negative targets ($M = 572.77$, $SD = 147.67$), while responses yielding a negative effect were emitted faster to negative targets ($M = 543.36$, $SD = 166.65$) than to positive targets ($M = 597.57$, $SD = 162.65$). The interaction between target valence and response type was also significant when means calculated over participants were subjected to an ANOVA over targets, $F_2(1, 58) = 8.18$, $MSE = 11,598.05$. All other RT effects (including the effect of response type) as well as all PE effects were non-significant (largest $F_1 = 2.04$, all $F_2 < 1$).

As in Experiment 1, affective correspondence between an eliciting stimulus and the effect of the to-be-emitted response to this stimulus resulted in faster responses than affective non-correspondence, this time in the absence of a main effect of response type. This lends further support to the idea that affective action effect feature codes can get included in an action's cognitive representation, to then influence response production. Affective feature code integration and the resulting affective correspondence effect could well rely on the same underlying associative mechanisms that result in operant or classical conditioning. Nevertheless, it is clearly different from a conditioning effect in the sense of a general effect on the speed, intensity, of frequency with which responses are emitted (i.e. a main effect of response type

as obtained in Experiment 1 but not in Experiment 2). Instead, what is crucial here is that the speed of emitting a particular response depends on the match between the valence of the effect of the response and the valence of the presented stimulus (i.e. an interaction between target valence and response type).

In Experiment 2, an additional manipulation was implemented, aimed at increasing the magnitude of the affective compatibility effect. In line with previous demonstrations of strategic influences on automatic information processing, we reduced the task-irrelevance of the affective connotation of the target words. The rationale for this manipulation was largely pragmatic. In fact, any manipulation bearing promise to amplify a possible compatibility effect, without interfering with the reliance of such an effect on affective action effect feature integration, would have done. Notwithstanding the fact that this manipulation was pragmatically inspired, one may be tempted to interpret the results of Experiment 2 with respect to the degree to which affective processing of word valence proceeds automatically (i.e. independent of intention or task-relevance). Indeed, the affective compatibility effect was larger in Experiment 2 than in Experiment 1, both nominally (a mean difference between corresponding and non-corresponding trials of 32 ms in Experiment 1 and 48 ms in Experiment 2) and in effect size (defined as the mean difference between corresponding and non-corresponding trials in proportion to the SD of this difference: 0.52 for Experiment 1 and 0.88 for Experiment 2). One could argue that this reflects the boosting impact of strategic factors on automatic affective processing. However, there are a number of other differences between both experiments that may account equally well (or even better) for the difference in effect magnitude. For instance, average RTs were markedly longer in Experiment 1 than in Experiment 2 (see General discussion). It is a well documented fact that spatial Simon effects are highly sensitive to the time frame between direct response activation (driven by irrelevant stimulus information) and voluntary response generation processes (driven by relevant stimulus information), and that therefore the average time to process relevant stimulus information can have a dramatic impact on the emergence and size of a Simon effect (e.g. Hommel, 1996; Hommel et al., in press; however, see De Houwer et al., 2001). Furthermore, the test targets had all been evaluated in the course of the training phase in Experiment 2, but not in Experiment 1. This may have increased the accessibility of the affective connotation of the targets, which may in turn have resulted in stronger automatic response priming in Experiment 2 (Fazio, 2001), independent of intention or task-relevance during the test phase. As such, and given the fact that the issue of strategic influences on affective processing was not our first concern anyway, we prefer to refrain from any conclusion regarding strategic factors in affective processing on the basis of the present results.

General discussion

In two experiments, reliable affective compatibility effects were obtained: Participants were faster to react to the grammatical category of a target if its affective connotation corresponded to the affective valence of the effect produced by the correct response. In Experiment 1, no targets were presented during a preceding training phase. In Experiment 2, target-response assignment was regularly switched in the course of training and test phase, so that the consistent response-effect assignment did not result in a consistent contingency between target category and effect. Taken together, these manipulations minimise the plausibility that the correspondence effects observed would be due to target-effect learning. Therefore, an account for the observed affective compatibility effect in terms of mere stimulus congruity is unlikely.⁴

Instead, we believe that the affective compatibility effect depends on response-effect learning. We are thus inclined to conclude that affective effect feature codes (and presumably other codes representing subjective, not directly perceivable features of an action's effects) can become part of the cognitive representation of an action. Moreover, these affective action effect feature codes can be activated by stimuli with a corresponding affective connotation, such as positive and negative words.

It is interesting to note that mean RTs were markedly shorter in Experiment 2 than in Experiment 1. In Experiment 2, targets were already presented for 300 ms before participants were cued about which task to perform (grammatical categorisation if the target subsequently turned yellow versus affective categorisation if the target turned blue). The shorter RTs in Experiment 2 presumably reflect the fact that participants already initiated response selection before they knew whether they actually had to perform the response. The fact that a substantial affective compatibility effect was nevertheless obtained presumably indicates that irrelevant stimulus information may not only influence early response generation processes (response selection), but also late response generation processes such as response initiation and execution. This complements recent evidence showing that also action-effect compatibility (the level of consistency between an action and the effects that it yields) not only affects response selection, but also response initiation and execution (Kunde, Koch, & Hoffmann; Anticipated action effects affect the selection, initiation and execution of actions; submitted for publication).

One can conceive of at least two possible mechanisms that may be responsible for associative affective compatibility effects as obtained here. The affective reactions to the positive and negative action effects presumably include various sorts of physiological, bodily reactions. This second-order action feedback may become integrated in the respective action representations. To the extent that effectively valenced words elicit similar bodily reactions, direct response activation may thus in the present experiments result from dimensional overlap at the level of bodily feedback produced by target words and action effects. According to such an account, action representations may consist entirely of perceptual feature codes, albeit not only direct, action produced feedback codes, but also second-order feedback codes activated by one's reaction to an action's effects. However, it is not clear to what extent words with a positive or negative connotation and without direct personal implication, as used in the present experiments, may be believed to arouse much bodily reaction. And even if they do, it is far from certain that such bodily reactions would show much similarity to the affective reactions elicited by the administration or omission of an unpleasant action effect.

An alternative account would be to suppose that dimensional overlap occurs at a more abstract, purely cognitive level. There is ample evidence that all stimuli encountered by an organism are automatically evaluated (Fazio, 2001; Hermans, De Houwer, & Eelen, 1994), and that this automatic stimulus evaluation involves the activation of evaluative tags in the semantic system (e.g. Bargh, Chaiken, Raymond, & Hymes, 1996; De Houwer & Hermans, 1994). This implies that a semantic feature code representing the affective connotation of an action's effects gets activated upon each occurrence of an action effect. If this code gets integrated in the representation of the action that yields its activation, then dimensional overlap between targets and actions comes about at the semantic level: Upon presentation of a target, a semantic code representing the affective connotation of the target is activated. This semantic code is according to this account either part of the required response, in which case response facilitation may occur, or part of the opposite response, in which case a response conflict may arise. Such an account implies that action effect feature codes need not be strictly perceptual, but may also be of a rather abstract and general (i.e. semantic) nature. This conforms to recent evidence suggesting that action effect integration may generalise to semantically related effects (Hommel, Alonso, & Fuentes, Acquisition and generalization of action effects; submitted for publication). Furthermore, even though common coding theories as the Theory of Event Coding (Hommel et al., in press) do not explicitly seem to predict such abstract affective action effect feature code integration, they can be easily adapted to accommodate non-perceptual effect feature code integration. The common coding space is held to be composed of codes representing distal and general rather than proximal and

⁴As one of the reviewers pointed out, if the observed compatibility effects relied on stimulus-effect learning, one would also expect the affective compatibility effect to increase in the course of the test phase of Experiment 1, as no target stimuli were presented in the training phase. Analyses with sub-block as an additional factor revealed no such increase of the affective compatibility effect; if anything, the compatibility effect was larger in the first sub-block than in the second sub-block.

specific effect features anyway (Prinz, 1992). We would simply suggest that these codes might be even more abstract than already claimed by the Theory of Event Coding, so that the common coding space is a truly cognitive space, instead of a merely perceptual space (i.e. also includes codes representing non-perceptual effect features).

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References

- Bargh, J. A., Chaiken, S., Raymond, P., & Hymes, C. (1996). The automatic evaluation effect: unconditional automatic attitude activation with a pronunciation task. *Journal of Experimental Social Psychology*, 32, 104–128.
- Bovens, N., & Brysbaert, M. (1990). IBM PC/XT/AT and PS/2 Turbo Pascal timing with extended resolution. *Behavior Research Methods, Instruments, and Computers*, 22, 332–334.
- Brewer, B. (1993). The integration of spatial vision and action. In N. Eilan, R. McCarthy & B. Brewer (Eds.), *Spatial representation: problems in philosophy and psychology* (pp. 294–316). Oxford, UK: Blackwell.
- De Houwer, J., Crombez, G., Baeyens, F., & Hermans, D. (2001). On the generality of the affective Simon effect. *Cognition and Emotion*, 15, 189–206.
- De Houwer, J., & Eelen, P. (1998). An affective variant of the Simon paradigm. *Cognition and Emotion*, 12, 45–61.
- De Houwer, J., & Hermans, D. (1994). Differences in the affective processing of words and pictures. *Cognition and Emotion*, 8, 1–20.
- Dinsmoor, J. A. (1977). Escape, avoidance, punishment: where do we stand? *Journal of the Experimental Analysis of Behavior*, 28, 83–95.
- Elsner, B., & Hommel, B. (2001). Effect anticipation and action control. *Journal of Experimental Psychology: Human Perception & Performance*, 27, 229–240.
- Fazio, R. H. (2001). On the automatic activation of associated evaluations: an overview. *Cognition and Emotion*, 15, 115–141.
- Gibson, J. J. (1979). *The ecological approach to visual perception*. Boston: Houghton Mifflin.
- Greenwald, A. G. (1970). Sensory feedback mechanisms in performance control: with special reference to the ideomotor mechanism. *Psychological Review*, 77, 73–99.
- Hasbroucq, T., & Guiard, Y. (1991). Stimulus-response compatibility and the Simon effect: toward a conceptual clarification. *Journal of Experimental Psychology: Human Perception and Performance*, 17, 246–266.
- Hazeltine, E. (in press). The representational nature of sequence learning: evidence for goal-based codes. In W. Prinz & B. Hommel (Eds.), *Attention & performance, Vol. XIX: Common mechanisms in perception and action*. Oxford: Oxford University Press.
- Hermans, D., & De Houwer, J. (1994). Affective and subjective familiarity ratings of 740 Dutch words. *Psychologica Belgica*, 34, 115–139.
- Hermans, D., De Houwer, J., & Eelen, P. (1994). The affective priming effect: automatic activation of evaluative information in memory. *Cognition and Emotion*, 8, 515–533.
- Hermans, D., De Houwer, J., & Eelen, P. (2001). A time course analysis of the affective priming effect. *Cognition and Emotion*, 15, 143–165.
- Hoffmann, J., Sebold, A., & Stöcker, C. (2001). Irrelevant response effects improve serial learning in serial reaction time tasks. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, 27, 470–482.
- Hommel, B. (1996). The cognitive representation of action: automatic integration of perceived action effects. *Psychological Research*, 59, 176–186.
- Hommel, B. (1997). Toward an action-concept model of stimulus-response compatibility. In B. Hommel & W. Prinz (Eds.), *Theoretical issues in stimulus-response compatibility* (pp. 281–320). Amsterdam: North-Holland.
- Hommel, B. (1998). Perceiving one's own action – and what it leads to. In J. S. Jordan (Ed.), *System theories and a priori aspects of perception* (pp. 143–179). Amsterdam: North-Holland.
- Hommel, B., Müsseler, J., Aschersleben, G., & Prinz, W. (in press). The theory of event coding (TEC): a framework for perception and action planning. *Behavioral and Brain Sciences*.
- James, W. (1890). *The principles of psychology*. New York: Dover Publications.
- Kerzel, D., Bekkering, H., Wohlschläger, A., & Prinz, W. (2000). Launching the effect: representations of causal movements are influenced by what they lead to. *The Quarterly Journal of Experimental Psychology*, 53A, 1163–1185.
- Kornblum, S., Hasbroucq, T., & Osman, A. (1990). Dimensional overlap: cognitive basis for stimulus-response compatibility: a model and taxonomy. *Psychological Review*, 97, 253–270.
- Kunde, W. (2001). Response-effect compatibility in manual choice reaction tasks. *Journal of Experimental Psychology: Human Perception & Performance*, 27, 387–394.
- Kunde, W., Hoffmann, J., & Zellmann, P. (2002). The impact of anticipated action effects on action planning. *Acta Psychologica*, 109, 137–155.
- Lu, C. H., & Proctor, R. W. (1995). The influence of irrelevant location information on performance: a review of the Simon and spatial Stroop effects. *Psychonomic Bulletin and Review*, 2, 174–207.
- O'Leary, M. J., Barber, P. J., & Simon, J. R. (1994). Does stimulus correspondence account for the Simon effect? Comments on Hasbroucq and Guiard (1991). *Psychological Research*, 56, 203–209.
- Prinz, W. (1990). A common-coding approach to perception and action. In O. Neumann & W. Prinz (Eds.), *Relationships between perception and action: Current approaches* (pp. 167–201). Hillsdale, NJ: Erlbaum.
- Prinz, W. (1992). Why don't we perceive our brain states. *European Journal of Cognitive Psychology*, 4, 1–20.
- Proctor, R. W., & Vu, K.-P. L. (in press). Eliminating, magnifying, and reversing spatial compatibility effects with mixed location-relevant and irrelevant trials. In W. Prinz & B. Hommel (Eds.), *Attention & performance, Vol. XIX: Common mechanisms in perception and action*. Oxford: Oxford University Press.
- Rescorla, R. A. (1968). Pavlovian conditioned fear in Sidman avoidance learning. *Journal of Comparative and Physiological Psychology*, 65, 55–60.
- Ridderinkhof, K. R. (in press). Activation and suppression in conflict tasks: empirical clarification through distributional analyses. In W. Prinz & B. Hommel (Eds.), *Attention & performance, Vol. XIX: Common mechanisms in perception and action*. Oxford: Oxford University Press.
- Simon, J. R. (1990). The effects of an irrelevant directional cue on human information processing. In R. W. Proctor & T. G. Reeve (Eds.), *Stimulus-response compatibility* (pp. 31–86). Amsterdam: North-Holland.
- Zhang, H. (2000). The Simon effect and its reversal in three-choice Hedge and Marsh tasks: evidence for irrelevant stimulus-response compatibility and stimulus congruity. *Journal of Experimental Psychology: Human Perception and Performance*, 26, 1018–1037.
- Ziebler, M., & Nattkemper, D. (in press). Effect anticipation in action planning. In W. Prinz & B. Hommel (Eds.), *Attention & performance, Vol. XIX: Common mechanisms in perception and action*. Oxford: Oxford University Press.