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ORIGINAL ARTICLE

Joint action changes valence-based action coding in an implicit attitude task

Anna Stenzel[1] · **Roman Liepelt**[1]

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Abstract Recent studies suggest that co-acting with another person induces a problem to discriminate between one's own and the other's actions which can be resolved by emphasizing action features that discriminate best between both persons' actions in a given task context. Mostly, overt action features like the spatial position of responses have been suggested as discriminating action features. In the present study, we tested whether non-externally perceivable, covert action features can be used for resolving the action discrimination problem during joint action. Therefore, we compared task performance between a joint and an individual version of the Go/Nogo Association Task, a task requiring the association of a valence to the response. We found a larger implicit attitude effect in the joint than in the individual setting for person-related (*self* and *other*, Experiment 1) as well as for non-person-related attitude objects (*fruit* and *insect*, Experiment 2) suggesting that the weight of valence information is increased in the internal coding of responses when valence discriminates between both responses. In contrast, we found a smaller implicit attitude effect in a person present setting than an individual setting (Experiment 3) indicating that the enhanced implicit attitude effect observed in the joint settings of Experiments 1 and 2 is not due to social facilitation. Our results suggest that action discrimination during joint action can rely on covert action features. The results are in line with the referential coding account, and specify the kind of action features that are represented when sharing a task with another person.

Introduction

Interacting with other humans is a key aspect of our daily life. Whether we carry a heavy object together, cook a delicious meal or communicate via the Internet—humans have developed outstanding skills optimizing the way in which we interact with others.

The cognitive mechanisms that enable successful interaction have recently become a focus in psychological research. Simple go/nogo tasks like the joint Simon task (Sebanz, Knoblich, & Prinz, 2003), the joint Flanker task (Atmaca, Sebanz, & Knoblich, 2011), or the joint SNARC task (Atmaca, Sebanz, Prinz, & Knoblich, 2008) have been used to experimentally study the differences in cognitive processing underlying individual and joint action. The paradigm that triggered some of the core cognitive models about task sharing is the joint Simon task (Sebanz et al., 2003), which is an adopted variant of the standard Simon task (Simon, Hinrichs, & Craft, 1970). In the standard Simon task, one of two stimuli (e.g., a diamond and a square) is randomly presented to either the left or right side of a monitor, and one single participant responds to one of both stimuli with a left and to the other with a right button press. The Simon effect refers to the finding that responses are usually faster when the position of the stimulus and the position of the response button are compatible than when they are incompatible. In the joint version of the Simon task, a standard Simon task is distributed across two persons, so that each person performs a go/nogo task in response to only one of the two stimuli. Just like in the standard Simon task, responses are usually faster when

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✉ Anna Stenzel
anna.stenzel@uni-muenster.de

✉ Roman Liepelt
roman.liepelt@uni-muenster.de

[1] Institute for Psychology, University of Muenster, Fliednerstraße 21, 48149 Münster, Germany

stimulus and response position are compatible than when they are incompatible, which has been called the “social Simon effect” or “joint go/nogo Simon effect.” Remarkably, when one (single) participant performs the same go/nogo task alone (individual go/nogo task), usually no stimulus–response (S–R) compatibility effect is observed (e.g., Sebanz et al., 2003; Liepelt, Wenke, Fischer, & Prinz, 2011).

The joint go/nogo Simon effect has mostly been explained by the action and task co-representation account (Sebanz et al., 2003; Sebanz, Knoblich, & Prinz, 2005), suggesting that each person automatically represents the action and task of the co-actor (i.e., the stimulus the other person needs to respond to and the action the other person has to perform when this stimulus appears according to a given task rule) in a functionally similar way as one’s own action and task (Sebanz et al., 2003, 2005). However, recently more parsimonious explanations, like the referential coding account (Dolk et al., 2011, 2014; Dolk, Hommel, Prinz, & Liepelt, 2013), and the actor co-representation account (Philipp & Prinz, 2010; Wenke et al., 2011) have been suggested for the joint go/nogo Simon effect. The referential coding account is rooted in the theory of event coding (TEC; Hommel, Müsseler, Aschersleben, & Prinz, 2001), which assumes that actions are cognitively represented by codes of their sensory consequences, independent of whether they are self-generated or generated by another person (Dolk et al., 2014). These codes represent features like the color, sound, speed, direction, or location of an action. When two actions are cognitively represented by similar features (e.g., the click sounds that are produced by the button presses of two persons in a joint Simon task), there is a need to cognitively discriminate between self-related and other-related action events. As action selection relies on activating the feature codes of the required response, it has been hypothesized that emphasizing on an (unique) action feature of the required response that discriminates between the actions of both persons in a given task context resolves the discrimination problem. As the spatial position (left, right) of both actions is a highly distinctive feature in the joint Simon task, the spatial information can be weighted more strongly in the internal coding of actions (Memelink & Hommel, 2013) to discriminate between both responses. A spatial coding of each actor’s action as left and right in turn induces dimensional overlap between spatial stimulus and spatial response features (Kornblum, Hasbroucq, & Osman, 1990) leading to faster responses when both features are compatible than when they are incompatible. As no alternative action event is present when performing the go/nogo Simon task alone, there is no problem to discriminate between one’s own and another person’s action, so that the go/nogo Simon effect is usually absent in the individual go/nogo task.

The key feature that has been suggested for response discrimination in the joint Simon task is the spatial position of the action (Dittrich, Dolk, Rothe-Wulf, Klauer, & Prinz, 2013; Dolk et al., 2011, 2013, 2014), which is a feature that is inherently part of the response due to the given experimental setting, and is clearly perceivable as it is external to the body (overt response feature). In line with this finding, a recent study suggests that also other overt response features, such as the color of a glove the participant is wearing, can be used for action discrimination during joint action when the stimuli in a Simon task contains color instead of space as the task irrelevant feature (Sellaro, Dolk, Colzato, Liepelt, & Hommel, 2015). However, not only overt features, but also features that are not externally perceivable (covert action features) are integrated into the cognitive representation of actions, and are used for action selection and control (Beckers, De Houwer, & Eelen, 2002; Eder, Rothermund, & De Houwer, 2013; Eder, Rothermund, De Houwer, & Hommel, 2014). These covert action features might depend on prior knowledge. Imagine for example reaching out your hand in order to shake the hand of a new colleague. If the colleague is a friendly person, the handshake will probably be experienced as a pleasurable action, as it is a first step to get into contact. However, when knowing that this new colleague has a bad cold, the handshake might be experienced as an unpleasant action as it increases the risk of catching a cold. Hence, although a handshake per se has not a fixed (positive or negative) value, it can become associated with a value depending on prior knowledge. This example illustrates that actions do not only contain overt features (like the spatial position, color, or sound), but are also often associated with covert features (like a valence information).

It is a fully open question whether covert action features can be used for action discrimination during joint action or whether action discrimination solely relies on overt response features. The answer to this question is of theoretical importance, as it specifies the representational nature of features that are considered in joint action control. If we would find evidence that non-externally perceivable features can be used to resolve the response discrimination problem, this would indicate that internal states of other persons are represented during task sharing. Further, showing that covert action features can be used for action discrimination would support a core assumption underlying the referential coding account (Dolk et al., 2013). This assumption holds that all kinds of features can be used to resolve the response discrimination problem when these features represent a unique feature of the required response that discriminates best in a given task context.

Established behavioral paradigms that require the integration of a covert feature (i.e., a valence) into the response representation (De Houwer, 2001, 2003) are the Implicit Association Task (IAT; Greenwald, McGhee, & Schwartz, 1998) and the Go/Nogo Association Task (GNAT; Nosek & Banaji, 2001). Both tasks are used to measure attitudes toward certain objects. Attitudes can be considered as connections between an object in memory and an evaluation thereof (Fazio, 1990, 2007; Olson & Fazio, 2009). An example for a robust and well-established implicit attitude effect is the finding that people usually more easily associate words belonging to the category *self* with positive words than negative words, and words of the category *other* with negative words than positive words (Greenwald & Farnham, 2000). This can be measured with the GNAT by presenting words either belonging to one of two valence categories (*good* and *bad*) or to one of two target categories (*self* and *other*) on a computer screen. In each trial, a single word belonging to one of these four categories is presented. In separate blocks, participants are asked to respond by pressing a single-response button (go-trial) whenever a word is presented that belongs to one target or one valence category (e.g., *self* + *good*) and to withhold responses (nogo-trial) when a word is presented which does not belong to these two categories (in the given example *other* + *bad*). Participants usually respond faster and make fewer errors when they respond to *self* + *good* or *other* + *bad* (compatible category pairs) than when they respond to *self* + *bad* or *other* + *good* (incompatible category pairs). The difference in response times or sensitivity indices (d-prime in signal detection theory) between compatible and incompatible category pairs is typically considered as a measure of the attitude a person has toward the respective attitude object (Nosek & Banaji, 2001).

How a valence information (i.e., a covert feature) is integrated into the response representation, and how this integrated information leads to dimensional overlap between stimulus and response features has been described in detail for the IAT by De Houwer (2001, 2003). As the GNAT is like a go/nogo version of the IAT, the same reasoning can be applied to the GNAT. As outlined above, one valence category and one target category are mapped onto a single-response button in the GNAT, so that the response becomes associated with the valences of both categories in a short-term association process. The assignment of valences to responses varies block wise. In compatible blocks (e.g., when responding to *self* + *good*), the response button is associated with one single positive valence, as the category *self* and the category *good* are both positively valenced. In an incompatible block (e.g., when responding to *self* + *bad*), the button is associated with two ambiguous valences: a positive valence for *self* and a negative valence for *bad*. On the stimulus side, the relevant feature for action selection is the category a stimulus word belongs to. Dimensional overlap is induced by the irrelevant stimulus feature, which is the valence of the category a stimulus word belongs to (De Houwer, 2001). This valence information has become associated with the category in a long-term association process. When performing the GNAT, the similarity between the valence of the category a stimulus word belongs to and the response valence varies, leading to a variation of dimensional overlap between stimulus and response features. In a compatible block, the response button is associated with one single valence (either a positive valence for *self* + *good* or a negative valence for *other* + *bad*). All stimulus words the participant needs to respond to in a compatible block share the same valence with the response, leading to fast responses and low error rates according to the dimensional overlap model (Kornblum et al., 1990). In contrast, in incompatible blocks, the response button is associated with two contrasting valences so that there is a lower similarity between the single valence of a stimulus and the two response valences. This leads to slower responses and higher error rates in incompatible blocks compared to compatible blocks.

There is an important difference between the GNAT or IAT and classical S–R compatibility tasks like the Simon task. In the Simon task, the dimensional overlap between stimulus and response features concerns an overt feature of the response (its spatial position) (Hommel, 2011) that is kept constant throughout the task, and a task irrelevant feature of the stimulus (its spatial position) varying from trial to trial. So, in the Simon task, dimensional overlap between stimulus and response features is varied by a change of stimulus features, while response features are kept constant throughout the whole task. This is why S–R compatibility varies trial wise in the Simon task. In contrast, in the IAT or GNAT, the degree of dimensional overlap between stimulus and response features is modulated by a variation of covert response features (i.e., the valence of a response), while the irrelevant stimulus features (i.e., the valence associated with the category a stimulus word belongs to) are kept constant. As the response features are not inherently part of the response, but need to be associated with the response by an active mapping process requiring cognitive resources and practice, the features of the response are defined block wise. Accordingly, the compatibility between stimulus and response features varies block wise (De Houwer, 2003).

The aim of the present study was to test if covert features, that are not inherently part of a response, but become integrated into the response representation by task instructions, can be used for resolving the action discrimination problem in a joint version of the GNAT. Doing this, the present study tests one of the core assumptions of the referential coding account holding that in principle all kinds of features can be used to resolve the response discrimination problem during joint action if these features discriminate the responses of both partners in a given task context. To do so, we developed a new joint version of the GNAT. Participants performed a GNAT measuring implicit associations for the attitude objects *self* and *other* alone (individual setting) and together with another person (joint setting). As many joint action paradigms are go/nogo tasks, which participants perform alone and together with another person, the GNAT—a go/nogo task in its standard version—was perfectly suited to investigate the present research question. In the joint setting, both participants performed exactly the same go/nogo task as in the individual setting, while the go-categories of one participant were nogo-categories for the other (e.g., when one participant responded to *self* + *good*, the other participant responded to *other* + *bad*).

Referential coding assumes that the discrimination problem during joint action is resolved by emphasizing features that distinguish best between events in a given task context. In compatible blocks of a joint GNAT, a single valence is associated with each response. As each person responds to the nogo-categories of the partner, both responses are associated with a contrasting valence in compatible blocks, so that the valence feature represents a unique feature suited to discriminate between responses, and hence valence can be weighted more strongly in the internal coding of responses. In incompatible blocks, the response of each person is associated with a positive as well as a negative valence, which is why action discrimination in incompatible blocks of the joint setting needs to rely on other response features than the valence information. Therefore, we would expect an improvement in performance in compatible blocks of the joint setting compared to the individual setting, but no performance difference between both settings in incompatible blocks. These differences in performance should lead to a larger S–R compatibility effect in the joint than in the individual setting.

As the dependent variable of the GNAT, we report response times (RTs) in all experiments, because response times consistently yielded higher internal consistencies (as measured by the split-half reliability) than sensitivity indices (split-half reliability averaged across all three experiments: for RTs = 0.89, for sensitivity indices = 0.54; see Table 1 for detailed values, and Valiente et al. (2011) for a similar observation regarding split-half reliabilities in the GNAT).

Experiment 1

In Experiment 1, we tested whether actively sharing a GNAT with another person increases the weight of covert discriminating response features in the internal coding of responses compared to a situation in which participants perform the same go/nogo task alone. Following the typical logic of joint action paradigms, participants performed a GNAT alone (individual setting) and together with another person (joint setting), while both participants were taking turns in responding. If valence information is used to discriminate between responses during the joint GNAT, we predicted a larger S–R compatibility effect (i.e., RTs in incompatible blocks minus RTs in compatible blocks) in the joint than in the individual setting due to speeded up RTs in compatible blocks of the joint setting.

Method

Participants

Based on previous joint action studies using a within-subjects design (e.g., Dolk et al., 2013; Liepelt, Stenzel, & Lappe, 2012), we chose a sample size of sixteen participants (5 male; 15 right-handed; $M_{\text{age}} = 24.00$ years,

Table 1 Split-half reliabilities (with Spearman–Brown correction) for response times (RT) and sensitivity indices (d-prime)

	Individual setting				Joint or person present setting				Mean
	o + g or i + g	o + b or i + b	s + g or f + g	s + b or f + b	o + g or i + g	o + b or i + b	s + g or f + g	s + b or f + b	
Exp. 1 RT	0.92	0.92	0.94	0.91	0.83	0.95	0.90	0.77	0.89
Exp. 1 d-prime	0.72	0.79	0.68	0.78	0.49	−0.52	0.48	0.71	0.52
Exp. 2 RT	0.96	0.97	0.97	0.86	0.90	0.95	0.96	0.86	0.93
Exp. 2 d-prime	0.17	0.82	0.76	0.58	0.30	0.23	0.61	0.74	0.53
Exp. 3 RT	0.84	0.87	0.89	0.83	0.82	0.90	0.88	0.89	0.86
Exp. 3 d-prime	−0.07	0.69	0.61	0.76	0.74	0.77	0.68	0.46	0.58

o + *g* other + good, *o* + *b* other + bad, *s* + *g* self + good, *s* + *b* self + bad, *i* + *g* insect + good, *i* + *b* insect + bad, *f* + *g* fruit + good, *f* + *b* fruit + bad

$SD_{\text{age}} = 4.95$ years, range 19–35 years). All participants received course credit points or monetary reward for participation. Participants had normal or corrected-to-normal vision, were naïve with regards to the hypotheses of the experiment, and gave their written informed consent prior to participating. The study was conducted in accordance with the ethical standards laid down in the 1975 Declaration of Helsinki.

Apparatus

For stimulus presentation, we used Matlab with the Psychtoolbox (Kleiner, Brainard, & Pelli, 2007) running on an Apple PC. All stimuli were displayed on a 20-in. CRT monitor at a viewing distance of 60 cm. The left and right command key of an Apple keyboard served as response keys. The distance between the centers of both response keys was 15.3 cm (each response key had the same distance to the midline of the monitor).

Stimuli

Good and *bad* were used as valence categories and *self* and *other* as target categories. For each valence category, we used the German translation of eight stimulus words taken from Nosek and Banaji (2001) or words with a similar meaning (e.g., "excellent", "wonderful" for *good*, and "evil", "disgusting" for *bad*; see Table 2). For each target category, we chose eight German stimulus words taken from Bluemke and Friese (2011) and variations thereof (e.g., "I", "my" for *self*, and "you", "your" for *other*; see Table 3). We used stimulus words that could clearly be associated with the respective category. Further, we matched stimulus words for the two valence categories and the two target categories in their total number of letters (*self* 36 letters, *other* 35 letters; *good* 57 letters, *bad* 57 letters). All stimulus words were presented in the center of a monitor on a black background. Stimulus words of the target categories were written in white, whereas stimulus words of the valence categories were written in green (see Fig. 1). Target category labels (written in white) were shown in the upper left and right corners, and valence category labels (written in green) in the lower left and right corners of the screen (16 cm to the left or right and 13.5 cm below or above the center of the monitor). Just like in the original study by Nosek and Banaji (2001), participants received visual feedback about the accuracy of their response: After correct responses (hit or correct rejection), a green "O" was displayed 6.7 cm below the stimulus words, and after incorrect responses (miss or false alarm) a red "X" was presented. Stimulus words, category labels, and feedback letters were 1.3 cm in height.

Table 2 List of stimulus words for the valence categories used in Experiments 1, 2, and 3

English Good	German Gut	English Bad	German Schlecht
Excellent	Exzellent	Repulsive	Abstoßend
Joyful	Freudig	Evil	Böse
Friendly	Freundlich	Disgusting	Eklig
Glad	Froh	Cruel	Grausam
Great	Großartig	Miserable	Miserabel
Super	Super	Abominable	Scheußlich
Terrific	Toll	Nasty	Übel
Wonderful	Wunderbar	Yucky	Widerlich

Table 3 List of stimulus words for the target categories used in Experiments 1 and 3

English Self	German Selbst	English Other	German Anderer
Own	Eigen	Foreign	Fremd
I	Ich	You (gen/nom)	Du
My (nom, m/n)	Mein	Your (nom, m/n)	Dein
My (nom, f)	Meine	Your (nom, f)	Deine
My (gen, f)	Meiner	Your (gen, f)	Deiner
My (gen, m/n)	Meines	Your (gen, m/n)	Deines
Me (dat)	Mir	You (dat)	Dir
Me (acc)	Mich	You (acc)	Dich

acc accusative, *dat* dative, *gen* genitive, *nom* nominative, *f* feminine, *m* masculine, *n* neutral

Task and procedure

All participants performed the GNAT alone (individual setting) and together with another participant (joint setting) (see Fig. 1). The order of task settings was counterbalanced across pairs of participants.

Each participant was randomly assigned to either the left or the right chair at the beginning of the experiment, and kept this seating position in the joint and the individual setting. The left person responded to the two category labels presented on the upper and lower left side of the monitor using the left response button, whereas the right person responded to the two category labels on the right side using the right response button. Participants were instructed to press the response button as fast and as accurately as possible when a word appeared that belonged to one of the categories they should respond to in a given block. In the joint setting, go-trials for one participant were nogo-trials for the other participant. To control for perceptual differences between the joint and the individual setting, the stimuli and task were identical in both settings,

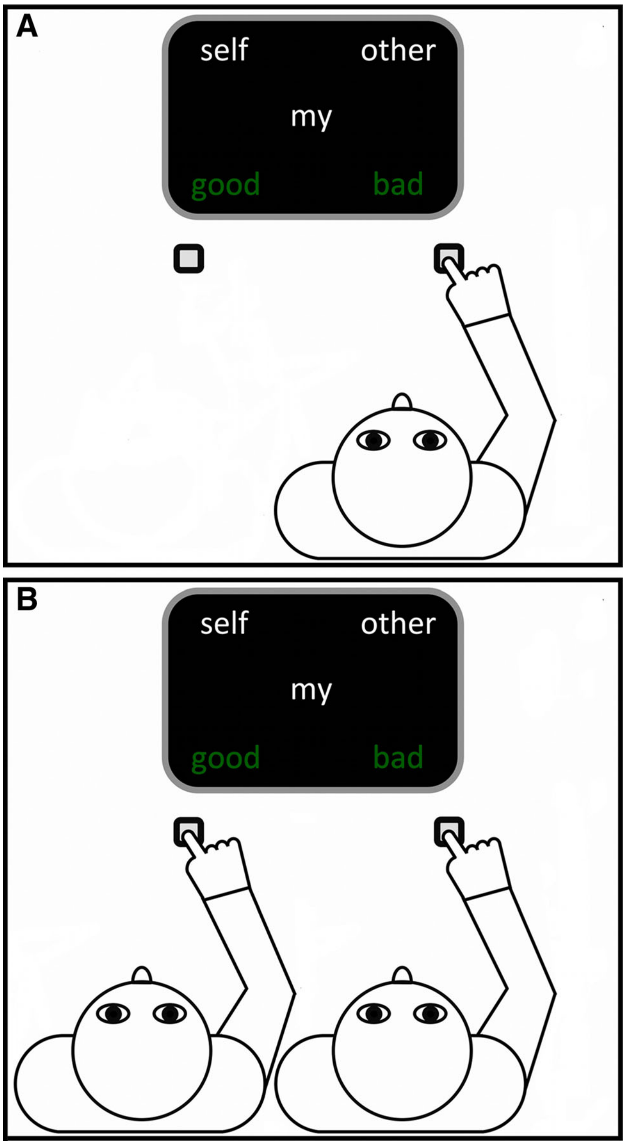

Fig. 1 Schematic illustration of the experimental setup used in Experiment 1. Each participant performed a Go/Nogo Association Task (GNAT) alone (individual setting, **a**) and together with another person responding to the other part of the go/nogo task (joint setting, **b**). As a reminder for the participants of which categories they should respond to in a given block, the task relevant categories were displayed on the left and right side of the monitor (left person responded to left categories, right person responded to right categories). Each person responded to all four possible combinations of target and valence categories (e.g., in Exp. 1: *self* + *good*, *self* + *bad*, *other* + *good*, *other* + *bad*). Stimulus words were presented in the center of the screen. Whenever a stimulus word belonged to one of the two task relevant categories, the participant responded with a button press

which is why also in the individual setting category labels were shown on both sides of the monitor, although the participant had to respond only to the categories on his/her side (see Fig. 1). Also, an empty chair remained besides the participant in the individual setting.

Both, the individual and the joint setting consisted of four practice blocks and eight experimental blocks. Like in the procedure used by Nosek and Banaji (2001), the practice blocks were administered first in order to practice discriminating words of the target and valence categories. In two practice blocks, stimulus words of both valence categories (*good* and *bad*) were presented, and it was the participant's task to respond to words of the category *good* in one block and to *bad* in another block. In the other two practice blocks, stimulus words of both target categories (*self* and *other*) were presented, and the participant responded in one block to *self* and in another block to *other*. Each practice block consisted of 20 trials (50 % go- and 50 % nogo-trials). Stimulus words were presented in random order within each practice block. The order of practice blocks was randomized. Each of the eight experimental blocks, which participants performed afterward, comprised 16 practice trials followed by 60 critical trials (50 % go- and 50 % nogo-trials). Stimulus words of all four categories were presented in random order. The task for the participant was to press the response button whenever a stimulus word belonged to one target category (e.g., *self*) or to one valence category (e.g., *good*). During the course of the experiment, each person responded to all four possible combinations of target and valence categories (i.e., *self* + *good*, *self* + *bad*, *other* + *good*, *other* + *bad*). In accordance with Nosek and Banaji (2001), the response deadline decreased in the course of the experiment in order to make the task more difficult. The response deadline was 1000 ms for the first four experimental blocks, and 833 ms for the last four experimental blocks. For each response deadline, every category combination (i.e., *self* + *good*, *self* + *bad*, *other* + *good*, *other* + *bad*) was chosen once and in random order.

Each trial began with the presentation of a stimulus word for 1000 ms (practice blocks and first four experimental blocks) or 833 ms (last four experimental blocks). Responses could be given within this time window. Afterward, feedback about the accuracy of the response (correct responses: green "O", error: red "X") was displayed for 200 ms together with the stimulus word. In the joint setting, a trial was classified as correct only if the responses of both participants were correct. Following feedback, there was a constant inter-trial interval (ITI) of 300 ms before the next trial started. Labels for target and valence categories were displayed in the corners of the screen throughout the whole trial and ITI as a reminder of the categories participants had to respond to.

At the beginning of the experiment, participants were given a written instruction about the task. Afterward, the experimenter repeated the written instruction verbally. Then, the first practice block started. In the individual setting, one of both participants left the room, while the other one was performing the task. The experimenter stayed in the room throughout the whole experiment, quietly sitting at a table with her back to the participant.

Results

For the statistical analysis, only mean RTs of critical trials (performed during the experimental blocks) were analyzed. For the joint setting, mean RTs were calculated separately for each participant. We coded the category pairs *self* + *good* and *other* + *bad* as compatible, and the category pairs *self* + *bad* and *other* + *good* as incompatible. We performed a 2 × 2 × 2 analysis of variance (ANOVA) including the within-subjects factors setting (individual vs. joint), attitude object (self vs. other), and compatibility (compatible vs. incompatible) for mean RTs of critical trials. The size of implicit attitude effects was calculated by subtracting the mean RTs in compatible trials from the mean RTs in incompatible trials (compatibility effects). The results of Experiment 1 are shown in Fig. 2.

Response times

Prior to RT analysis, all trials in which the participant performed an error (individual setting 6.4 %, joint setting 7.1 %) or trials in which RTs were faster than 150 ms (0 % in both settings) were excluded. The counterbalancing factor order (individual setting first vs. joint setting first) did not interact with the main comparison of interest (namely the interaction of setting × compatibility), $F(1, 14) < 1$. Therefore, the results are reported collapsed across order.

A significant main effect of compatibility, $F(1, 15) = 90.73$, $p < 0.0001$, $\eta_p^2 = 0.86$, indicated faster RTs for compatible ($M = 496$ ms) than incompatible conditions ($M = 548$ ms). A significant interaction of the factors setting and compatibility, $F(1, 15) = 23.36$, $p < 0.001$, $\eta_p^2 = 0.61$, revealed that the size of the compatibility effect was different for the two task settings showing a larger compatibility effect for the joint setting (70 ms, $F(1, 15) = 107.93$, $p < 0.0001$, $\eta_p^2 = 0.88$) than the individual setting (35 ms, $F(1, 15) = 30.02$, $p < 0.0001$, $\eta_p^2 = 0.67$). This pattern was similar for both attitude objects, as indicated by a non-significant three-way interaction of attitude object, setting, and compatibility, $F(1, 15) < 1$. Planned post hoc comparisons revealed that this difference in the size of compatibility effects between the joint and the individual setting was due to significantly speeded RTs in compatible conditions of the joint setting compared to the individual setting ($F(1, 15) = 15.76$, $p = 0.001$, $\eta_p^2 = 0.51$, *self* + *good*: $t(15) = 3.20$, $p < 0.01$, *other* + *bad*: $t(15) = 4.21$, $p < 0.001$), with statistically comparable RTs for incompatible conditions ($F(1, 15) < 1$, $p > 0.05$, $\eta_p^2 < 0.01$, *self* + *bad*: $t(15) < 1$, $p = 0.63$, *other* + *good*: $t(15) < 1$, $p = 0.85$). All other main effects and interactions were not significant, all ps > 0.05.

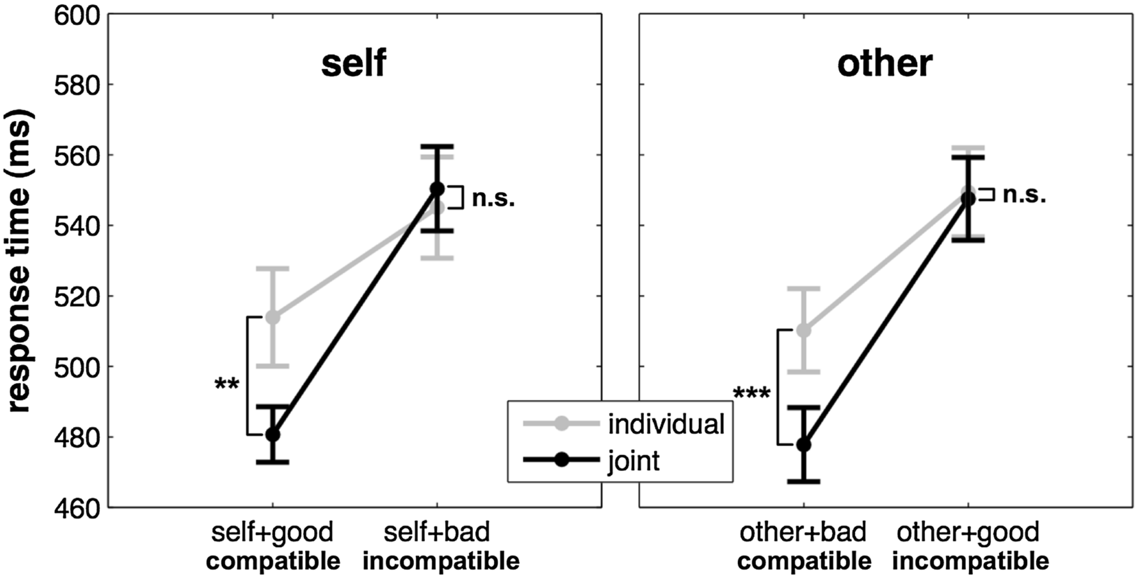

Fig. 2 Mean response times in Experiment 1 for the target categories *self* (*left panel*) and *other* (*right panel*) plotted separately for each combination of target categories (*self* and *other*) and valence categories (*good* and *bad*), and separately for the joint (*black lines*) and the individual setting (*light gray lines*). *Error bars* represent standard errors of the means. ***$p < 0.001$, **$p < 0.01$, $^{\text{n.s.}}p > 0.05$

To test whether the results might be explained by a speed-accuracy trade-off (SAT), we conducted the same ANOVA for mean error rates of critical trials. For the joint setting, mean error rates were again calculated separately for each participant. The analysis of error rates yielded a significant main effect of compatibility, $F(1, 15) = 53.12$, $p < 0.0001$, $\eta_p^2 = 0.78$, indicating less errors in compatible (3.4 %) than incompatible blocks (10.0 %). Speeded up RTs in compatible conditions were accompanied by fewer errors, whereas slower RTs in incompatible conditions were accompanied by more errors. All other main effects and interactions were not significant, all *p*s > 0.05. This suggests that the RT pattern cannot be explained by an SAT.

Discussion

In line with previous findings (e.g., Greenwald & Farnham, 2000), we found faster RTs for *self* + *good* and *other* + *bad* compared to *self* + *bad* and *other* + *good*. Critical to our research question, the size of the compatibility effect was about twice as large in the joint setting than the individual setting due to speeded RTs in compatible blocks. The results are in line with the assumption that the weight of valence information is increased in the internal coding of responses when valence represents a distinguishing feature between responses. This suggests that covert response features, which are not inherently part of the response, can be used to resolve the action discrimination problem during joint action.

However, joint task performance has alternatively been suggested to induce the requirement to distinguish between the self and the other person (actor co-representation account), which can be met by relying on all kinds of distinguishing criteria (Philipp & Prinz, 2010; Wenke et al., 2011). These enhanced self–other discrimination demands during joint action might not only concern action discrimination, but could also concern discrimination along other distinguishing dimensions. For example, it could be possible that the features integrated in the representation of the concepts *self* and *other* become more activated during joint action. Therefore, the enlargement of the implicit attitude effect for the attitude objects *self* and *other* observed in Experiment 1 could reflect altered cognitive representations of the self and the other person in a co-acting situation (actor discrimination) rather than reflecting a change in action representation along the valence dimension. To rule out this alternative interpretation, the finding of a higher implicit attitude effect in the joint than the individual setting for categories different than *self* and *other* is needed.

Experiment 2

In Experiment 2, participants performed a GNAT measuring attitudes toward non-person-related attitude objects in an individual and a joint setting. We chose the categories *fruit* and *insect* as target categories as these non-person-related categories have been shown to have a clear positive (*fruit*) and negative (*insect*) valence (e.g., Nosek & Banaji, 2001). The procedure was the same as in Experiment 1, with the only difference being the target categories used.

If the enlargement of the implicit attitude effect in the joint setting as compared to the individual setting we observed in Experiment 1 is due to a change in action representation along the valence dimension and not due to actor discrimination, we expected to find a larger compatibility effect in the joint than in the individual setting also for non-person-related attitude objects.

Method

Participants

A new set of sixteen participants took part in the experiment (3 males; all right-handed; $M_{\text{age}} = 23.44$ years, $SD_{\text{age}} = 6.73$ years, range 18–40 years). All participants fulfilled the same criteria and were treated in the same way as participants in Experiment 1.

Apparatus, task, and procedure

Apparatus, task, and procedure were the same as in Experiment 1.

Stimuli

The only difference between Experiment 1 and Experiment 2 concerned the stimulus words for the target categories. We chose *fruit* as the positively valenced target category and *insect* as the negatively valenced category. For each target category, we chose eight German stimulus words (e.g., “apple”, “orange” for *fruit*, and “ant”, “bumblebee” for *insect*; see Table 4). The words from each target category were roughly matched in number of letters (*insect* 58 letters, *fruit* 60 letters). For the valence categories (*good*, *bad*), we used the same words as in Experiment 1 (see Table 2).

Results

For statistical analysis, we coded the category pairs *fruit* + *good* and *insect* + *bad* as compatible, and *fruit* + *bad* and *insect* + *good* as incompatible. As in

Experiment 1, we calculated a 2 × 2 × 2 ANOVA including the within-subjects factors setting (individual vs. joint), attitude object (fruit vs. insect), and compatibility (compatible vs. incompatible) separately for mean RTs of critical trials. The results of Experiment 2 are shown in Fig. 3.

Response times

Again all trials in which the participant performed an error (individual setting 5.4 %, joint setting 4.8 %) or in which RTs were faster than 150 ms (0 % in both settings) were excluded from the statistical RT analyses. As the counterbalancing factor order (individual setting first vs. person present setting first) did not interact with the main comparison of interest (namely the interaction of compatibility × setting), $F(1, 15) = 3.87$, $p > 0.05$, $\eta_p^2 = 0.22$, the results are reported collapsed across order.

Table 4 List of stimulus words for the target categories used in Experiment 2

English Fruit	German Frucht	English Insect	German Insekt
Apple	Apfel	Ant	Ameise
Pomegranate	Granatapfel	Grasshopper	Grashüpfer
Lime	Limone	Bumblebee	Hummel
Mango	Mango	Dragonfly	Libelle
Orange	Orange	Maybug	Maikäfer
Physalis	Physalis	Caterpillar	Raupe
Gooseberry	Stachelbeere	Housefly	Stubenfliege
Lemon	Zitrone	Worm	Wurm

The main effect of compatibility was significant, $F(1, 15) = 104.17$, $p < 0.0001$, $\eta_p^2 = 0.87$, indicating faster RTs for compatible ($M = 497$ ms) than incompatible conditions ($M = 557$ ms). A significant interaction of setting and compatibility, $F(1, 15) = 9.18$, $p < 0.01$, $\eta_p^2 = 0.38$, revealed that the size of the compatibility effect was different for the two task settings showing a larger compatibility effect for the joint setting (69 ms, $F(1, 15) = 69.23$, $p < 0.0001$, $\eta_p^2 = 0.82$) than the individual setting (48 ms, $F(1, 15) = 85.11$, $p < 0.0001$, $\eta_p^2 = 0.85$). This pattern was similar for both target categories, as indicated by a non-significant three-way interaction of attitude object, setting, and compatibility, $F(1, 15) < 1$. Planned *t* tests revealed that the difference in the size of compatibility effects between the joint and the individual setting was due to significantly speeded RTs in compatible conditions of the joint setting compared to the individual setting ($F(1, 15) = 13.64$, $p < 0.01$, $\eta_p^2 = 0.48$, *fruit* + *good*: $t(15) = 2.91$, $p < 0.05$, *insect* + *bad*: $t(15) = 3.86$, $p < 0.01$), with statistically comparable RTs for incompatible conditions ($F(1, 15) < 1$, $p > 0.05$, $\eta_p^2 = 0.03$, *fruit* + *bad*: $t(15) = 0.91$ $p = 0.38$, *insect* + *good*: $t(15) = 0.45$, $p = 0.66$). A significant main effect of attitude object, $F(1, 15) = 21.39$, $p < 0.001$, $\eta_p^2 = 0.59$, indicated faster mean RTs for *fruit* (519 ms) than *insect* (534 ms). All other main effects or interactions were not significant, all *p*s > 0.05.

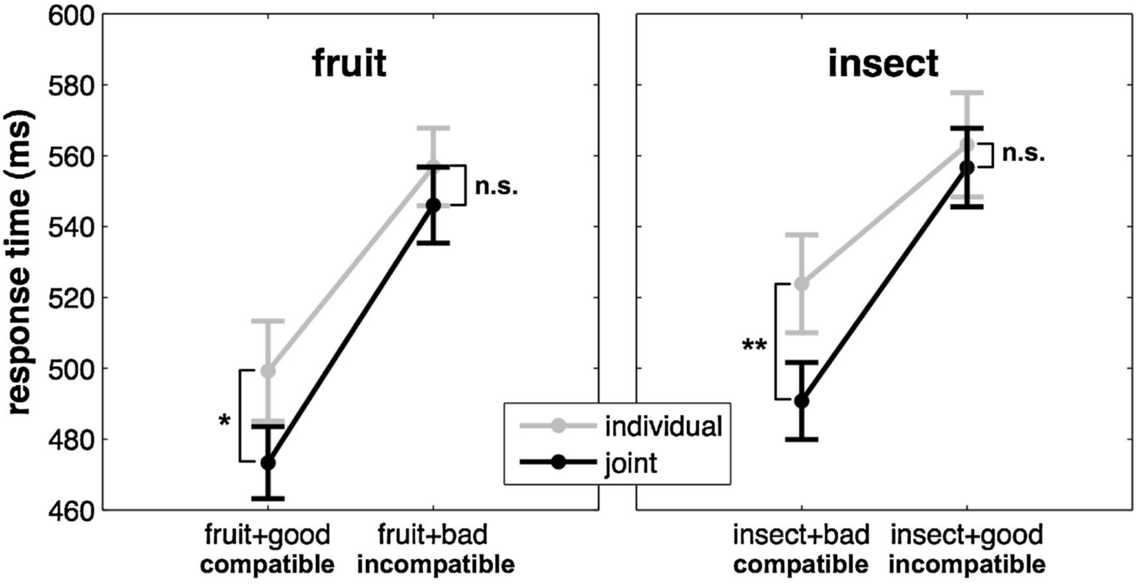

Fig. 3 Mean response times in Experiment 2 for the target categories *fruit* (*left panel*) and *insect* (*right panel*) plotted separately for each combination of target categories (*fruit* and *insect*) and valence categories (*good* and *bad*), and separately for the joint (*black lines*) and the individual setting (*light gray lines*). *Error bars* represent standard errors of the means. $^{**}p < 0.01$, $^{*}p < 0.05$, $^{\text{n.s.}}p > 0.05$

The analysis of error rates yielded a significant main effect of compatibility, $F(1, 15) = 51.17$, $p < 0.0001$, $\eta_p^2 = 0.77$, indicating less errors in compatible (2.9 %) than incompatible blocks (7.2 %). As in Experiment 1, speeded up RTs in compatible conditions were accompanied by fewer errors, whereas slower RTs in incompatible conditions were accompanied by more errors. This suggests that the RT pattern cannot be explained by an SAT. All other main effects and interactions were not significant, all $ps > 0.05$.

Discussion

In Experiment 2, we demonstrated that the modulation of the implicit attitude effect we observed in Experiment 1 for the attitude objects *self* and *other* also generalizes to non-person-related attitude objects (*fruit* and *insect*). Replicating previous studies (Nosek & Banaji, 2001), participants could more easily associate fruits with positive words and insects with negative words. Critically, actively sharing the GNAT with another person increased the compatibility effect for both target categories as compared to a situation where the same task was performed alone. As in Experiment 1, the enlargement of the compatibility effect was driven by speeded responses in compatible blocks, while response times for incompatible blocks were comparable for the joint and the individual setting. The replication of the results of Experiment 1 for non-person-related categories (*fruit* and *insect*) suggests that the enlargement of the compatibility effect in the joint as compared to the individual setting observed in the present experiments is due to a change in action representation along the valence dimension when acting together with another person. In line with the results of the first experiment, the present results suggest that covert action features can be used for action discrimination during joint action even though these features are not inherently part of a response, but become integrated into the action representation due to task requirements.

However, when performing a task together with another person, social facilitation/inhibition effects (Zajonc, 1965) might also influence task performance. In joint action tasks, social facilitation effects have often been observed in terms of speeded up responses when performing the task while being observed by another person as compared to a situation where the task is performed alone (e.g., Atmaca et al., 2011; Liepelt & Prinz, 2011; Liepelt, Wenke, & Fischer, 2013; Vesper, van der Wel, Knoblich, & Sebanz, 2011; Welsh, Higgins, Ray, & Weeks, 2007). Especially when a task is easy, humans usually show better performance in the presence of others (Guerin, 1986; Zajonc, 1965). If the task is complex or not well learned, the performance is likely to be impaired, which is called social inhibition (Aiello & Douthitt, 2001).

In the GNAT, compatible blocks could be regarded as a rather easy task. Therefore, speeded up RTs in compatible blocks of the joint setting might alternatively be caused by social facilitation on simple tasks. In order to test whether the enlargement of the compatibility effect observed in the first two experiments could be explained by social facilitation, we conducted another experiment in which we tested the effects of the mere presence of another person on implicit attitudes toward the attitude objects *self* and *other*.

Experiment 3

Experiment 3 was designed to test whether social facilitation/inhibition induced by the mere presence of another person could alternatively explain the finding of a larger compatibility effect in the joint setting as compared to the individual setting. Participants performed the *self–other* GNAT alone (individual setting) and together with another person. Different from Experiment 1, the other person now sat besides the participants without actively responding (person present setting). If the enhanced compatibility effect of the joint GNAT observed in Experiments 1 and 2 is due to social facilitation, one should find the same pattern of results on individual performance under conditions of social presence, that is, a larger compatibility effect in the person present setting than in the individual setting due to speeded responses in compatible blocks.

Method

Participants

A new set of twenty-four participants took part in the experiment (5 males; all right-handed; $M_{\text{age}} = 23.04$ years, $SD_{\text{age}} = 4.52$ years, range 18–38 years). All participants fulfilled the same criteria and were treated in the same way as participants in Experiment 1.

Apparatus and stimuli

Apparatus and stimuli were the same as in Experiment 1.

Task and procedure

Participants performed the GNAT alone (individual setting), and in the presence of another person, who did not respond to the alternative category (person present setting). Following the logic of Sebanz, Knoblich and Prinz (2003, Experiment 2), in the person present setting the other person merely sat besides the participant. The other person was instructed to quietly sit besides the participant, and to look at the monitor. The order of settings as well as the seating position of the participant (left or right) was counterbalanced across participants.

Results

As in Experiment 1, we coded the category pairs *self* + *good* and *other* + *bad* as compatible, and *self* + *bad* and *other* + *good* as incompatible. We calculated a 2 × 2 × 2 ANOVA including the within-subjects factors setting (individual vs. person present), attitude object (self vs. other), and compatibility (compatible vs. incompatible) for mean RTs of critical trials. The results of Experiment 3 are shown in Fig. 4.

Response times

Again all trials in which the participant performed an error (individual setting 5.8 %, person present setting 5.1 %) or in which RTs were faster than 150 ms (0 % in both settings) were excluded from the statistical RT analyses. As the counterbalancing factor order (individual setting first vs. person present setting first) did not interact with the main comparison of interest (namely the interaction of setting × compatibility), $F(1, 22) < 1$, results are reported collapsed across order.

The main effect of compatibility was significant, $F(1, 23) = 40.29$, $p < 0.0001$, $\eta_p^2 = 0.64$, with faster RTs for compatible ($M = 511$ ms) than incompatible ($M = 552$ ms) trials. The interaction of setting and compatibility was marginally significant, $F(1, 23) = 4.01$, $p = 0.06$, $\eta_p^2 = 0.15$, indicating a smaller compatibility effect in the person present setting (35 ms, $F(1, 23) = 24.57$, $p < 0.0001$, $\eta_p^2 = 0.52$) than in the individual setting (47 ms, $F(1, 23) = 43.85$, $p < 0.0001$, $\eta_p^2 = 0.66$). We further observed a significant interaction of attitude object and compatibility, $F(1, 23) = 9.71$, $p < 0.01$, $\eta_p^2 = 0.30$, indicating a larger compatibility effect for *self* (52 ms) than for *other* (30 ms), and a significant main effect of setting, $F(1, 23) = 5.43$, $p < 0.05$, $\eta_p^2 = 0.19$, indicating slower responses in the person present setting (536 ms) than in the individual setting (527 ms). The main effect of attitude object and all other interactions were not significant, all ps > 0.05.

Discussion

In Experiment 3, we tested whether the mere presence of another person modulates self- and other-related implicit attitudes. As in Experiment 1, we found a significant compatibility effect for both target categories, proving that participants could more easily associate *self* with *good* and *other* with *bad*. There was a tendency for a smaller compatibility effect in the person present setting than in the individual setting. This finding allows for two main conclusions. First, social facilitation effects cannot explain the findings of Experiments 1 and 2 showing enhanced implicit attitude effects when actively sharing the GNAT with another person. Second, a reduced implicit attitude effect when another person is present supports previous findings showing the malleability and context sensitivity of implicit

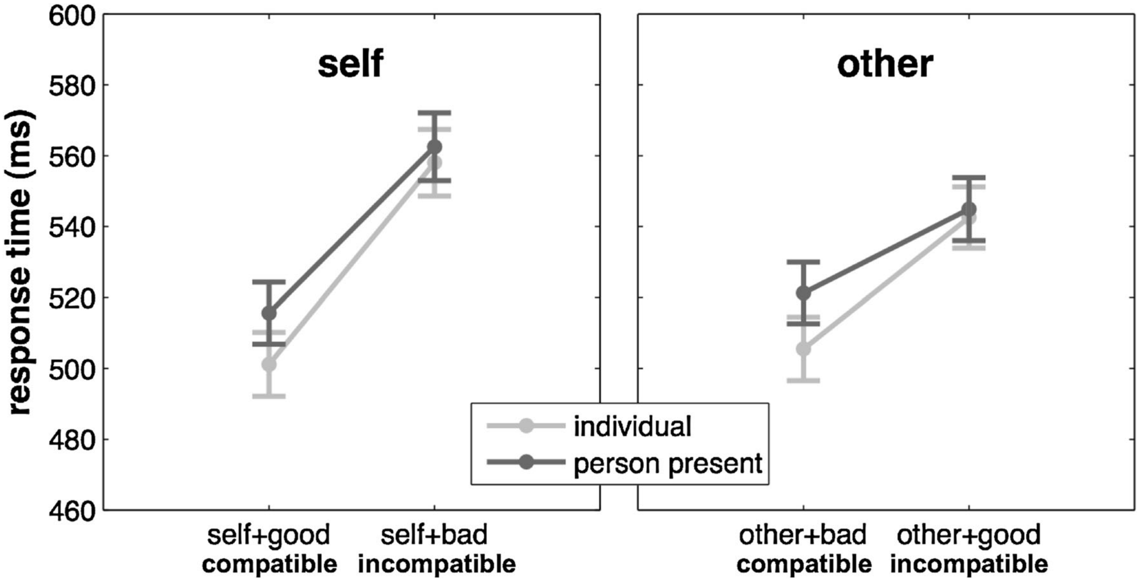

Fig. 4 Mean response times in Experiment 3 for the target categories *self* (*left panel*) and *other* (*right panel*) plotted separately for each combination of target categories (*self* and *other*) and valence categories (*good* and *bad*), and separately for the person present (*dark gray lines*) and the individual setting (*light gray lines*). *Error bars* represent standard errors of the means

attitude effects (Blair, 2002). We also found a general slowing in the person present setting as compared to the individual setting, suggesting that the mere presence of another person produced a social inhibition effect in Experiment 3 (Aiello & Douthitt, 2001; Zajonc, 1965).

General discussion

The referential coding account assumes that action features, like the spatial position or color of an action (i.e., overt action features), can be used to discriminate between actions when co-acting with others (Dolk et al., 2011, 2013, 2014; Sellaro et al., 2015). In the present study, we investigated for the first time if action discrimination during joint action can rely on covert action features (Beckers et al., 2002; Eder et al., 2013, 2014), which are not inherently part of an action, but are associated with an action by task instruction. To investigate this research question, we developed a new joint version of the GNAT—a task requiring the association of a valence to a response—which participants performed alone and together with another person.

In compatible blocks of the joint setting, the responses of both persons were associated with opposing valences. Therefore, the valence information could be used for action discrimination in this condition. In the first experiment, we observed typical implicit attitude effects for the categories *self* and *other* with faster responses when responding to *self* + *good* or *other* + *bad* than when responding to *self* + *bad* or *other* + *good* for the individual and the joint setting. For both target categories, the size of the implicit attitude effect was about twice as large in the joint than in the individual settng. The increase of the implicit attitude effect in the joint setting was driven by speeded up RTs in compatible blocks (*self* + *good*, *other* + *bad*) of the joint setting, while RTs in incompatible blocks (*self* + *bad*, *other* + *good*) did not differ statistically between the joint and the individual setting. These findings suggest that the valence information of both responses was used for action discrimination in the joint setting whenever this feature clearly discriminated between responses (i.e., in compatible blocks). The results of Experiment 2 revealed that also implicit attitude scores toward non-person-related categories (*fruit* and *insect*) are modulated when co-acting with another person. Just like in Experiment 1, implicit attitude effects for the categories *fruit* and *insect* were larger in the joint than in the individual setting driven by speeded responses in compatible blocks, while RTs in incompatible blocks did not differ statistically. This finding provides further support for the assumption that action coding along the valence dimension is modified when actively sharing the GNAT with another person. In Experiment 3, there was a tendency for a smaller compatibility effect when another person was present who merely sat besides the participant without responding than when performing the task alone. This pattern of results was the opposite pattern as observed in the first two experiments, where compatibility effects were larger when the task was shared with a co-actor who actively responded to the nogo-categories. These findings show that implicit attitude effects are by no means fixed, but seem to be sensitive to social context (Blair, 2002). The reliability of the social presence effect we observed in Experiment 3 is less pronounced than the finding of an enhancement of implicit attitude effects when two persons actively shared the task. While we could show the latter finding for person-related (Experiment 1) and non-person-related categories (Experiment 2), future studies will have to replicate the effect of social presence on implicit attitude effects before making strong conclusions about this effect. Most important for the present research question, the results of Experiment 3 rule out social facilitation as an explanation for the finding of increased compatibility effects when actively sharing a task with another person, which we observed in the first two experiments.

Our findings are not only in line with, but also extend the referential coding account (Dolk et al., 2011, 2013, 2014) by specifying the representational nature of the features that are used to resolve the action discrimination problem under joint action conditions. The results are in line with the core assumption of the referential coding account holding that in principle all kinds of features can be used to resolve the action discrimination problem during joint action. To resolve the discrimination problem, unique action features that discriminate best between the actions of two persons in a given task context are emphasized through intentional weighting (Memelink & Hommel, 2013). Our findings support the assumption that those action features are likely to be used for action discrimination which share features with the experimental stimuli (Sellaro et al., 2015). More precisely, the task irrelevant feature responsible for dimensional overlap has been suggested as a discriminating feature (Sellaro et al., 2015). Examples for these task irrelevant features are the spatial position in a typical joint go/nogo Simon task in which stimuli are presented to the left or right side (e.g., Dittrich et al., 2012, 2013; Guagnano et al., 2010), the color in a joint go/nogo Simon task in which stimuli are displayed on the same spatial position, but in different colors (Sellaro et al., 2015), and the valence of stimuli in the joint GNAT of the present study.

Our results suggest that action coding is quantitatively (not qualitatively) different when co-acting with another person on the task than when performing the same task alone. That is, even in the individual setting a valence is included into the response representation of the action, but the weight of this valence feature differs between compatible blocks of the joint and the individual setting, because valence represents a discriminating feature in these blocks. In the joint GNAT, the weight of the valence is enhanced in the internal coding of responses, so that the action discrimination problem is resolved. However, in order to change their action coding according to the covert response feature, participants seem to also consider these categories their co-actor responds to and the valence that is associated with these categories, suggesting that also non-externally perceivable response features of the other person seem to be registered during joint action.

One should also point out that besides the stimulus–response compatibility account for the GNAT effect (De Houwer, 2001, 2003), there are other accounts explaining implicit attitude effects. For instance, Rothermund and Wentura (2004) suggested that the saliency of the target and valence category rather than their valence becomes associated with a response and is thus the relevant feature for facilitating responses. As negatively valenced items as well as unfamiliar ones are more salient than positively valenced or familiar items (Rothermund & Wentura, 2004), valence and saliency are often confounded. For example, in a *self–other* GNAT, the category *other* is less familiar than *self* and hence more salient, and the category *bad* is more salient than *good*, as it is negatively valenced. When *other* and *bad* are mapped onto a response button, the response assignment is compatible with regards to the saliency of both categories. With this compatible response assignment, responses are faster as all target stimulus words have the same saliency as the response. When both categories do not correspond with regards to their saliency (e.g., in an *other* + *good* block), the response button is associated with two saliencies. Here, the single saliency associated with a stimulus word does not pre-activate responses as much as in a compatible block leading to slower responses. We think that it is not relevant for the interpretation of the present data whether categories are classified according to their valence or their saliency during the GNAT. Even if saliency and not valence was mapped onto a response, the discrimination problem induced during joint action could be resolved in a similar way as we outlined above. That is, in compatible blocks of the joint condition, the saliency could be used as a discriminating feature between both responses, as one participant would map two highly salient concepts onto his/her response button, and the other participant would map two low salient concepts onto his/her response button. In contrast, in incompatible blocks, the saliency would be the same for both responses, so that saliency could not be used to resolve the action discrimination problem. So, even if response coding was based on saliency and not on valence, we would expect the same response time pattern as observed in the present study.

In the present experiments, the effects we observed were confined to response times, and not to error rates. This may be explained by the fact that error rates were on a rather low level, which might be due to the choice of response deadlines. As shown by Nosek and Banaji (2001), shorter response deadlines are associated with more errors, so that the use of even shorter deadlines (like 666 or 500 ms) is likely to induce a higher percentage of errors. When using shorter deadlines, one might also find a difference of the implicit attitude effect between the joint and the individual setting for error rates.

The present results are also interesting for research testing contextual changes of implicit attitudes. Many studies suggest that automatic attitudes are flexibly constructed depending on situational social variables, and that scores on implicit measures of attitudes are malleable (Mitchell, Nosek, & Banaji, 2003). For example, in a study by Lowery, Hardin, and Sinclair (2001), European Americans showed less automatic racial prejudice after being instructed by a black experimenter compared to a white experimenter suggesting that interethnic contact reduced automatic prejudice against black people. However, there is an ongoing debate of whether a change in scores on implicit attitude tasks always reflects a change in the underlying mental representation of a concept (i.e., a change in the attitude). For example, Han, Czellar, Olson, and Fazio (2010, Experiment 1) showed that participants exhibited stronger racial bias in a traditional version of the IAT after having rated non-race-related items from a society's perspective compared to rating the same items from a personal perspective. As participants were not provided with any information that could have changed their racial attitudes, it is rather unlikely that a change in the underlying attitude had occurred. Based on their results, the authors suggested that a change in IAT scores might also reflect the perspective that was primed prior to performing the implicit association task rather than reflecting a real attitude change. Just like in the study by Han et al. (2010), we believe that a change in the underlying attitude toward the concepts used in our study is unlikely to have occurred, as we did not provide participants with any information about the attitude objects that could have changed their attitudes. Therefore, in line with the results by Han et al. (2010), our results may suggest that a change in implicit attitude scores can occur even if there is good reason to assume that the underlying attitude remained the same. While the results of Han et al. (2010) demonstrate that implicit attitude scores can vary depending on whose perspective was primed prior to the task, our results indicate that implicit attitude scores can change online when performing the task together with another person by a change in cognitive action representation.

Taken together, the present study shows that joint action enhances implicit attitude scores as compared to individual action. This enhancement was found for person-related as well as for non-person-related attitude objects. This modulation was caused by an increase in the weight of valence information in the coding of actions whenever the valence represents a clearly discriminating feature. Our results suggest that action discrimination during joint action can rely on covert action features that are associated with an action via task instructions, and must not be based on overt action features.

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