Journal of Cognitive Enhancement (2023) 7:276–289
https://doi.org/10.1007/s41465-023-00276-9

ORIGINAL RESEARCH

Transfer of Approach-Avoidance Training: Motoric or Goal-Related?

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Received: 1 March 2023 / Accepted: 24 October 2023 / Published online: 3 November 2023

Abstract

Approach-avoidance training (AAT) procedures were developed with the prospect that they can modify action impulses to approach or avoid specific stimuli. Research suggested that the outcome of AAT procedures is mediated by training-induced changes in implicit response tendencies. This study investigated whether AAT procedures affect implicit response tendencies because of a training of goal-related responses or due to a training of motoric actions effecting approach and avoidance. Participants in three internet-based experiments (total $n = 514$) were trained to approach and avoid two fictitious social groups by steering a symbolic representation of the self towards and away from group members. They alternated between the training task and a flanker-like test task that probed for training-induced changes in response tendencies consistent with the trained action or with the trained AA goal. Results demonstrated a transfer of relations between the stimuli and AA goals from training to test tasks. In contrast, relations to the motoric acts subserving these goals had no effect on implicit response tendencies. It is concluded that a relation to approach- and avoidance related goals, and not to the motoric action, were established with the AAT procedure. Implications for associative and inferential accounts of AAT effects are discussed.

Keywords Approach-avoidance training · Implicit response bias

Human motivation is characterized by basic motivations to approach desired and to avoid undesired objects, states, or events (Elliot et al., 2013). The underlying motivational impulse is often automatic, producing maladaptive behaviours that are at odds with the individual's explicit wishes and desires. Accordingly, these motivations are often difficult to change with verbal instructions and traditional means. In recent years, psychologists have therefore invented new computerized interventions that aim to directly change the relatively automatic or implicit motivational processes involved in approach and avoidance (for reviews see Kakoschke et al., 2017; Wiers et al., 2020). These new interventions are here collectively referred to as *approach-avoidance training tasks* (AAT) because they seek to change motivational tendencies by the repeated execution of a behaviour that is congruent or incongruent with the motivational impulse to approach and avoid. The critical feature is that the trained response has a relation to approach and avoidance that could be intrinsic to the performed behaviour (e.g., approach-related flexion versus avoidance-related extension of the arm) or extrinsic on the level of the action goal representation (e.g., the goal to increase versus decrease the distance; for a discussion of these conceptualizations, see Eder & Rothermund, 2008). The underlying assumption is that after a sufficient number of pairings during the training, the stimuli assigned to the trained behaviour become associated with the motivational orientation that is linked to the trained action. In line with this assumption, many studies showed that AAT procedures can influence social (e.g., racial attitudes; Kawakami et al., 2007), emotional (e.g. phobic reactions, Amir et al., 2013), cognitive (e.g., math skills; Kawakami et al., 2008), and consumptive outcomes (e.g. alcohol consumption, Wiers et al., 2011).

AAT interventions were developed with the prospect of changing action impulses leading to maladaptive behaviours underlying clinical disorders (e.g., addiction) or socially unwanted behaviours (e.g., racial discrimination). As a consequence of this pragmatic orientation, much less consideration was given to the mental processes underlying

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AAT effects. This "black box" also encompasses the question: what is trained by AAT procedures? On the basis of associative learning theory, some have argued that a specific response tendency is trained during AAT (e.g., Kakoschke et al., 2017; Wiers et al., 2011). Based on the principle of mere spatiotemporal contiguity, the behavioural training creates an associative link between training stimuli and the trained action that generates an automatic tendency to approach or avoid the associated stimulus even when not demanded by the situation or task. In support of this claim, some studies found that AAT effects were indeed mediated by training-induced changes in automatic response tendencies measured with a separate response task. For example, Sharbanee and colleagues (2014) trained a participant group with a feedback-based joystick task that zoomed pictures of non-alcoholic beverages towards them and pictures of alcoholic beverages away from them (alcohol-avoid group), whereas another group received the reverse assignment (alcohol-approach group). In addition to training, so-called 'assessment trials' were intermixed in which participants had to touch an alcohol picture or a non-alcohol picture on a touchscreen as quickly as possible. Reaction times in these trials were analysed for the computation of an implicit stimulus-response (S-R) response bias as a function of the alcohol-approach versus alcohol-avoid training condition. Results demonstrated a training-induced change in the alcohol-approach bias: the alcohol-avoid group touched alcohol pictures slower after the training than the alcohol-approach group. In a statistical mediation analysis, the alcohol-approach bias was significantly related to the quantity of alcohol consumption, suggesting that the effect of AAT on alcohol consumption was mediated by a training-induced modification of S-R associations.

However, several studies did not find an analogous mediation effect (see e.g., Dickson et al., 2016; Machulska et al., 2016; Taylor & Amir, 2012; Wiers et al., 2011). Furthermore, according to an alternative account of AAT effects—the propositional inference account—a behavioural training is not even necessary, because knowledge about relations between stimuli and AA-related behaviours ("I approach stimulus X and avoid stimulus Y") and inferences about the evaluation of stimuli based on this relational knowledge ("I like X more than Y because I have repeatedly approached it") can be formed without behavioural training (Van Dessel et al., 2019). In fact, studies demonstrated that the mere instruction to approach or avoid a stimulus is sufficient to produce changes in explicit and implicit evaluations of that stimulus (Van Dessel et al., 2015, 2020). Additional studies showed that AAT effects require awareness of relevant contingencies (Van Dessel, De Houwer, & Gast, Dessel et al., 2016a) and are moderated by beliefs about the implications of the learned relation (e.g., the belief that avoiding fatty food improves health; see Van Dessel, Hughes et al., 2018).

To sum up, accounts of AAT effects on the mental process level differ in their emphasis on a behavioural training with approach-avoidance related actions. According to the inferential account, a behavioural training is not necessary and only instrumental in the acquisition of relational stimulus-action knowledge underlying propositional inferences. This propositional knowledge could eventually be transferred from one task to another task without involvement or active contribution of the motor system, as demonstrated by instruction-based AAT effects. In contrast, for the associative account, the motor activity effecting approach/avoidance is an integral part of the associative structure that generates a response tendency. Associative links between stimuli and motoric actions should therefore transfer from one task to another task, as indexed by training-induced changes of response tendencies in indirect response tasks.

The Present Research

The present study examined these hypotheses by researching whether trained actions (keypresses) effecting approach/approach during the AAT are automatically re-activated when the associated training stimuli are processed in another task (the so-called 'test task'). Figure 1 shows the basic design of the experiments. In AAT blocks, participants were asked to steer a manikin, representing the self, towards or away from fictitious group member names depending on the group membership with presses of the up and down arrow keys. The group member name always appeared at the screen centre and the manikin either started above or below the name (counterbalanced start position). After sufficient training, participants worked on a test block in which they had to react to the font style of the target word. The presented word was the name of one of two social groups to which the names presented during the AAT task belonged. Importantly, the start position of the manikin in the test block was always opposite to where the manikin started in the AAT trials. Thus, participants now had to press the opposite response key to steer the manikin towards to or away from the word. Actions performed during the test task could hence either be consistent with the trained actions during the AAT on the goal level (same AA goal but different keypress) or on the behavioural level (press of the same key but different AA goal).

Since its introduction more than twenty years ago (De Houwer et al., 2001), the symbolic manikin task has been used by many studies for the measurement of motivational wants and desires (e.g., striving for high vs. low-caloric food, Neimeijer et al., 2015; alcohol, Field et al., 2011;

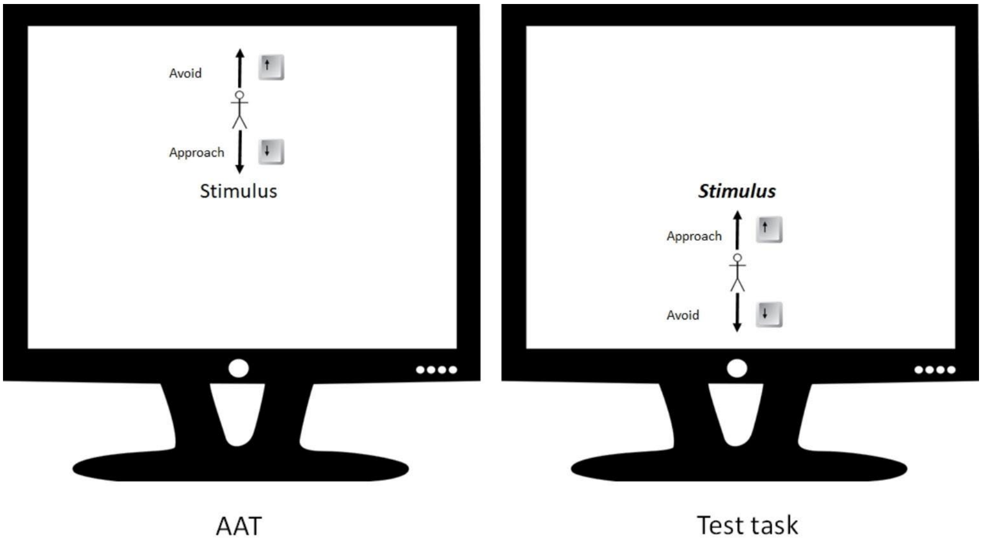


Fig. 1 Graphical illustration of the AAT task (left) and test task (right) in Study 1. In the AAT block, a manikin representing the participant's self either always appeared above a stimulus (group member name) or below it (counterbalanced start position). Task instructions were to move the manikin towards or away from specific group members with presses of the up and down arrow keys. In the test task block, the manikin always started at the opposite location to the AAT and participants were to approach/avoid the stimulus depending on its font style (bold versus italics)

tobacco, Mogg et al., 2003; cannabis, Field et al., 2006). Studies also demonstrated that the manikin task is sensitive to motivational changes after training and clinical interventions (Neimeijer et al., 2015; Van Dessel, Eder et al., 2018). In a systematic comparison of approach-avoidance tasks using standardized affective stimuli (affective words, spider pictures), the manikin task outperformed the joystick task (pushing/pulling of a lever) and a joystick task with action feedback (visual zooming in/out of stimuli) with respect to the sensitivity to the motivational valence and reliability of measurement (Krieglmeyer & Deutsch, 2010). In addition, the manikin task was also more strongly related to self-reported fear of spiders, compared to the joystick task, and only the manikin task was sensitive to the motivational valence of stimuli when measured indirectly. These measurement properties make the manikin task well suited for the present research objectives.

Using our study design with intermixed training and test tasks, we examined the following research hypotheses: According to the associative account, the AAT task should create an association between specific stimuli and the trained keypress effecting approach/avoidance. This memory association should linger after a temporary switch to the test task, becoming active when the associated training stimulus is encountered again. As a result, participants should perform better in test trials (lower reaction times, fewer errors) in which the same key must be pressed to trigger the task-instructed manikin movement (motor-consistent trial) compared to the opposite key (motor-inconsistent trial). For the inferential account, by contrast, propositional representations are acquired during the training that specify the relation between specific stimuli and intended ends (i.e., approach/avoidance), with the keypress controlling approach/avoidance being an exchangeable means to the intended end. Accordingly, participants should perform better in test trials in which the stimulus-end relation is consistent with acquired proposition (goal-consistent trial) compared to when they are conflicting (goal-inconsistent trial).

Study 1 pitted both predictions against each other, because in the test task of this study motor-consistent test trials were always goal-inconsistent and motor-inconsistent trials were always goal-consistent (see Fig. 1). It is of course also possible that both components, propositional stimulus-end relations *and* stimulus-response associations, are acquired through AAT (Gawronski & Bodenhausen, 2011). This possibility was examined in follow-up experiments. In Study 2, an additional test condition with a novel response set (mouse movements instead of keypresses) was created in which propositional stimulus-end relations could operate without potential interference by trained stimulus-response associations. Study 3 included an additional test condition in which acquired S-R associations and propositional stimulus-end relations were perfectly confounded (i.e., both mental processes should trigger response tendencies in the same direction). These 'new' conditions were compared in each experiment with a test condition in which S-R associations and stimulus-relations were opposing (as described for Study 1). If S-R associations and propositional relations generate implicit response tendencies conjointly, then the training effect indexed by a change in implicit response tendencies should be larger in the new test conditions.

Data on evaluative reactions to the training stimuli (social groups) as a function of the AAT were not collected in this study because our research questions exclusively focused on training-dependent changes in implicit response bias as training outcomes (see also our preregistration documents at OSF). However, unpublished data from additional experiments in our laboratory confirmed that the described AAT procedure is in principle effective in producing training-consistent evaluative changes.

Study 1

Study 1 pitted stimulus-end relations against stimulus-response relations: goal-consistent trials were motor-inconsistent and motor-inconsistent trials were goal-consistent (see Fig. 1). The dependent variables of primary interest were the reaction time to initiate the manikin movement and the accuracy of the responses. Performance measures were analysed as a function of consistency with training (consistency with stimulus-approach/avoidance vs. stimulus-key-press relations) and number of training blocks. The number of training blocks was included as an additional variable in the analyses to investigate the development of an implicit approach bias with training.

If training of stimulus-end relations is more effective for a change in implicit response tendencies, behavioural performance should be better in goal-consistent test trials relative to goal-inconsistent test trials. In contrast, a reverse facilitation effect is expected if training of stimulus-response associations would be more influential (i.e., better performance in goal-inconsistent relative to goal-consistent trials).

Method

Participants

We preregistered a data collection of $N = 100$ for a minimum sample size of $n = 80$ valid datasets that is sensitive to a small-to-medium effect size ($d_z = 0.32$) with a statistical power of $1\text{-}\beta = 0.80$ in a two-sided paired *t*-test. Data of $N = 103$ participants were collected online via the Prolific platform. Each participant received a monetary compensation of £2.50 in addition to a performance-contingent monetary reward (see below for details).

In line with our preregistered data-analysis plan, datasets of participants were excluded who (1) did not complete all trials (three participants); (2) had an error rate of 25% or greater on any of the following performance measures: (i) the action-goal reminder trials; (ii) the training trials; (iii) the test trials (six participants); (3) took longer than 50 min to complete the study (no exclusions). The final sample was $n = 94$ (51 females, 35 males, 2 other, 6 no gender data; $M_{\text{age}} = 33.5$ years, $SD = 10.7$). Informed consent was obtained from the participants and the study procedure was approved by our local ethics committee (see our *Ethics Approval Statement*).

Procedure

The experiment comprised two tasks: the AAT task and a flanker-like test task that probed for training-induced changes in automatic approach-avoidance tendencies. Both tasks alternated regularly in predictable order. In addition, so-called "goal-reminder trials" were intermixed within both tasks in which the participants were to respond to the words "Approach" and "Avoid" as quickly as possible with a corresponding movement of the manikin.

Manikin Training Task Participants first completed a practice task in which they pressed the up and down arrow keys of the computer keyboard to move a manikin, as a symbolic representation of the participant, either towards or away from a target word that appeared at the screen centre. In each trial, the manikin appeared in either the top or bottom half of the screen. After 750ms, the target word "Approach" or "Avoid" appeared and participants responded as quickly as possible by tapping an arrow key. The manikin then moved in the direction of the response key for 300ms. Task instructions were to respond so that the manikin moves towards the word "Approach" and moves away from the word "Avoid". If they responded incorrectly, an error message ("WRONG RESPONSE!!!") appeared for 2000 ms. If they did not respond within 2000 ms, an error message ("TOO SLOW!!!") appeared for 2000ms. After 50ms, the next trial started. Participants completed 16 trials of this task (half approach, half avoidance; of these, half with the manikin starting at the top and half with the manikin starting at the bottom).

Approach-Avoidance Training Task (AAT) Targets for the training were group member names of two fictitious groups, ending either with –nif (Niffites) or with –lop (Loopites). Participants were instructed to approach one group and to avoid the other (counterbalanced assignment). There were four names of Niffites ("Cellanif", "Eskannif", "Lebbunif", "Zallunif") and four names of Loopites ("Maasolop", "Neenolop", "Omeelop", "Wenaalop"). Each name was presented once per block. Procedure was the same as for the manikin training, except that the manikin always appeared either on the top half or on the bottom half of the screen (counterbalanced positioning).

Test Task In this task, the words "Niffite" and "Loopite" appeared in bold or italics. Participants were instructed to approach words in one font style and to avoid the other (counterbalanced assignment). The manikin always appeared on the opposite side of the screen to the training (i.e., if the manikin appeared in the top half during the AAT, it appeared in the bottom half during the test task and vice versa). Procedure was the same as in the other tasks.

Task Structure After the initial manikin training (performed in a single block), participants completed 12 AAT blocks and 12 test blocks with the tasks constantly alternating from training to test. Each task block included an additional four goal-reminder trials in which participants were to respond to the words "Approach" and "Avoid" (as in the manikin training task) with a corresponding manikin movement as quickly as possible. Each AAT block hence consisted of 8 trials (4 Niffites names, 4 Loopites names) and 4 goal-reminder trials (2 approach, 2 avoid). Each test block consisted of 8 trials with target words in bold or italics (2 Niffites in bold, 2 Niffites in italics, 2 Loopites in bold, 2 Loopites in bold) and an additional four goal-reminder trials (2 approach, 2 avoid). In total, participants completed 96 AAT trials, 96 test trials, and 96 goal-reminder trials.

Participants were explicitly informed that they would be alternating predictably between tasks where they would respond to a name and tasks where they would respond to a font. In addition, they were notified that if they succeed in responding correctly to 70% of the label trials and 70% of the name/font trials per block, they would receive an extra monetary reward (£0.05 per block; thus, potentially 24 x £0.05 = £1.20 in total) on top of the basis payment for participation. After each block, they received feedback on task performance, including whether they had achieved the reward criterion for that block.

Data Preparation and Data-Analytic Approach

In line with our preregistered data analysis plan, the first two task block pairs were excluded from the analyses as practice blocks. For RT analyses, trials in which the participant responded incorrectly or responded to slower than the participant's personal third quartile plus 1.5 interquartiles (5% of the data) were eliminated from analysis. This criterion removed 5% of the RT data.

Means of reaction times and error rates were calculated for training-consistent and training-inconsistent trials for two consecutive blocks and subjected to a within-subjects analysis of variance (ANOVA) with the factors *Consistency* (goal-consistent/motor-inconsistent, goal-inconsistent/motor-consistent) and *Training Progress* (block pairs 1–5). Training-induced changes in implicit response tendencies were examined with the test of a main effect of *Consistency*. An additional linear trend analysis of the interaction effect between Consistency and Training Progress using polynomial contrast coefficients explored whether the magnitude of the training effect is related to the number of training trials. Error rates were log transformed before analyses to correct for violation of normality; however, untransformed descriptive values are reported for ease of interpretation. The significance criterion was set to $p < .05$ for all analyses and Greenhouse-Geisser corrected values are reported after violation of sphericity.

Results

Correct performance in the AAT task ($M = 96.7\%$, $SD = 3.1\%$) and in the goal-reminder trials ($M = 96.3\%$, $SD = 3.7\%$) was very high.

In the rm-ANOVA of the reaction times in the test task with *Consistency* (training-consistent, training-inconsistent) and *Training Progress* (block pairs 1–5) as factors, the main effect of Consistency was significant, $F(1, 93) = 4.878$, $p = .030$, $\eta_p^2 = 0.050$. As shown in Fig. 2, RTs in goal-consistent/motor-inconsistent trials were shorter ($M = 586$ ms, $SE = 10.1$) than those in goal-inconsistent/motor-consistent trials ($M = 592$ ms, $SE = 10.2$). The main effect of *Training Progress* was also significant, $F(3.586, 333.485) = 9.681$, $p < .001$, $\eta_p^2 = 0.094$, with faster reaction times in later blocks. The interaction effect was not significant, $F(4, 372) = 0.286$, $p = .594$, $\eta_p^2 = 0.003$.

The linear trend analysis corroborated a linear reduction of reaction times with training progress, $F(1, 93) = 27.135$, $p < .001$, $\eta_p^2 = 0.226$. The linear trend of the interaction effect was however not significant, $F(1, 93) = 0.134$, $p = .715$, $\eta_p^2 = 0.001$.

In a corresponding rm-ANOVA of the (log-transformed) error rates, the main effect of *Consistency* was significant, $F(1, 93) = 10.947$, $p = .001$, $\eta_p^2 = 0.105$. Error rates were lower in goal-consistent trials ($M = 1.5\%$, $SE = 0.3$) compared to goal-inconsistent trials ($M = 2.9\%$, $SE = 0.4$). The main effect of *Block*, $F(3.58, 332.953) = 0.102$, $p = .982$, $\eta_p^2 = 0.001$, and the interaction effect, $F(3.482, 323.811) = 1.522$, $p = .202$, $\eta_p^2 = 0.016$, were not significant.

Discussion

Study 1 pitted the goal-training hypothesis against the motor-training hypothesis. The results are clear-cut: reactions to training stimuli were faster and less error-prone when the action goal assigned to the stimulus was consistent with the training, and the motoric action (keypress) inconsistent, relative to a condition in which the action goal was inconsistent and the keypress consistent with the training. This result demonstrates that stimulus-action goal relations dominated after training.

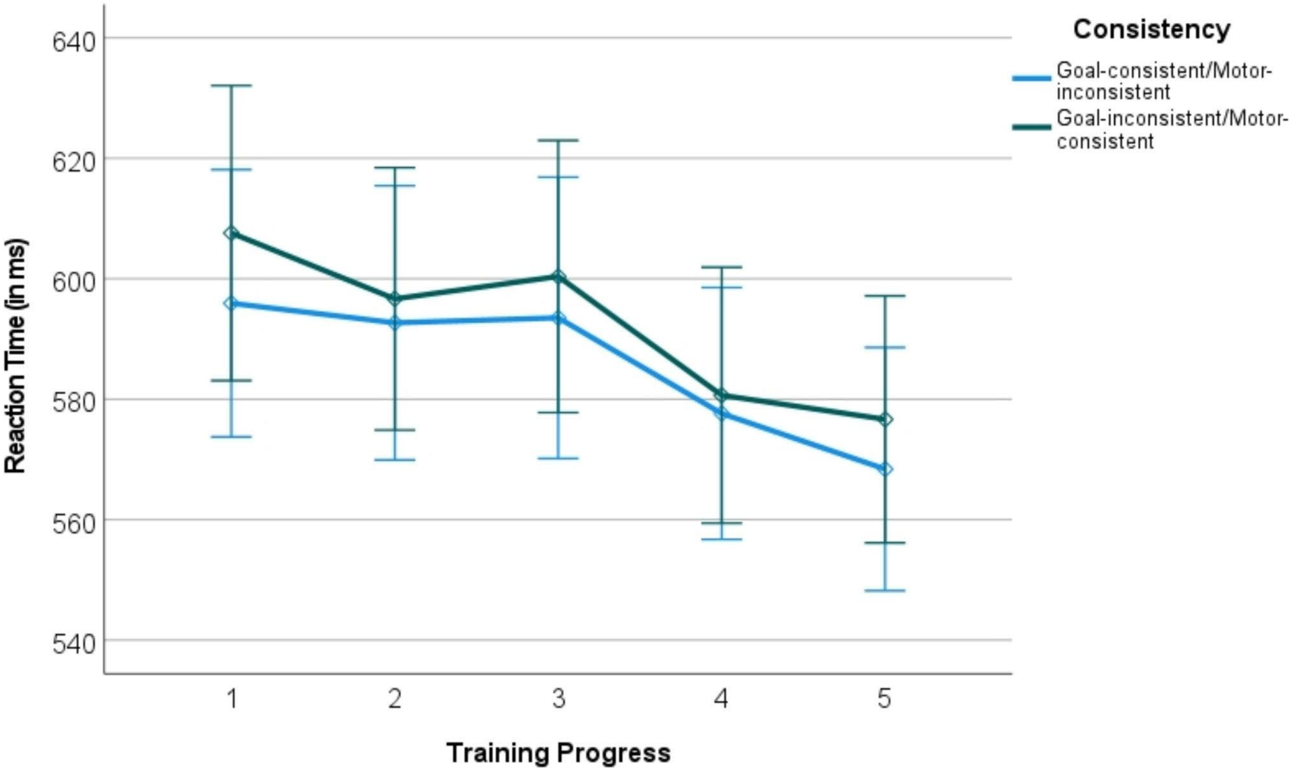


Fig. 2 Reaction times (in ms) in goal-consistent and goal-inconsistent trials as a function of training progress (aggregates of two test blocks) in Study 1. Note that goal-consistent trials were motor-inconsistent and goal-inconsistent trials motor-consistent. Error bars show the 0.95 confidence interval

The magnitude of the training effect did not increase with the number of training blocks. It should be noted that participants had already worked through two practice blocks before they started with training blocks. It is possible that the small number of AAT trials during task practice was already sufficient for knowledge acquisition about stimulus-action contingencies, in line with demonstrations of instruction-based AAT effects (Van Dessel et al., 2015; see also Eder et al., 2010). If so, the training effect may have reached a ceiling and thus was not increased further by additional training.

Study 2

In Study 1, goal-consistency and motor-consistency were mutually exclusive and the result showed that consistency with action goals dominated after training. This explanation does not preclude associations between training stimuli and motor actions that were overridden by the relation with action goals. This *motor-and-goal-training hypothesis* was examined in subsequent studies.

In our second study, we adopted a condition that retained the stimulus-end relation but removed incongruent stimulus-response relations. If knowledge about stimulus-end *and* stimulus-response relations is acquired during AAT, the training-induced consistency effect should be larger in the condition in which stimulus-end relations need not override incongruent stimulus-response relations (motor noninterference condition) relative to a condition in which both relations are incongruent (motor interference condition). The motor noninterference condition is implemented by using a new response set for the test task.

Method

Participants

We preregistered a minimum of $n = 199$ valid datasets for the detection of a small interaction effect size ($d_z = 0.2$) with acceptable statistical power ($1\text{-}\beta \geq 0.80$). Data of $N = 256$ participants were collected online via the Prolific participant recruitment platform (payment excluding performance-contingent bonus reward: £2.00). Exclusion criteria on the participant level were the same as those for Study 1. The final sample was $n = 221$ (86 females, 133 males, 2 other; $M_{\text{age}} =$ 29.9 years, $SD = 8.2$). Informed consent was obtained from the participants and the study procedure was approved by a local ethics committee (see our Ethics Approval Statement).

Design and Procedure

The experiment was identical to Study 1 except for the following point: After the first six block pairs (i.e., the first half), the response set used for the test task changed. In one half of the test blocks, participants responded with presses of the arrow keys, as in Study 1 (keypress response set). In the other half of the blocks, participants triggered manikin movements towards and away from the target word with movements of the computer mouse in forward and backward directions (computer-mouse response set). Each trial was initiated by either a press of the left arrow key in the keypress condition or by a mouse click on the starting position of the manikin in the mouse movement condition (to position the mouse cursor). The order of the response sets for the test task was counterbalanced across participants. The extra monetary reward per block was reduced to £0.02.

To summarize, after the initial manikin training task, participants either moved the manikin in the first six blocks of the test task with presses of the up and down arrow keys (keypress response set) or they triggered the manikin movement with forward and backward movements of the computer mouse (computer mouse response set). Half of the sample started with the arrow keys and the other half with movements of the computer mouse. After six AAT/test block pairs, the response set for the test task switched from arrow keys to mouse movement or vice versa.

Results

Correct performance in the AAT task ($M = 96.5\%$, $SD = 3.7\%$) and in the goal-reminder trials ($M = 95.4\%$, $SD = 3.9\%$) was very high.

Performance measures in the test task were analysed with a mixed ANOVA with the factors *Consistency* (goal-consistent vs. goal-inconsistent; within-subjects), *Response Set* (keypress vs. computer-mouse; within-subjects) and *Order of the Response Sets* (arrow keypress first vs. computer mouse movement first; between-subjects) as factors. Training progress (number of blocks) was not included due to the counterbalanced order of the response set conditions.

The ANOVA of the RTs in the test task yielded a significant main effect of *Consistency*, $F(1, 219) = 11.955$, $p = .001$, $\eta_p^2 = 0.052$ (see Fig. 3). Reaction times in training-consistent trials were faster ($M = 667$ ms, $SE = 9.2$) than those in training-inconsistent trials ($M = 676$ ms, $SE = 9.6$). The interaction between *Consistency* and *Response Set* was not significant, $F(1, 219) = 0.281$, $p = .597$, $\eta_p^2 = 0.001$. Planned comparisons confirmed a significant consistency effect in the keypress condition (ΔMs = 8 ms), $t(220) = 2.305$, $p = .022$, $d_z = 0.16$, and in the computer-mouse condition, (ΔMs = 10 ms), $t(220) = 2.618$, $p = .009$, $d_z = 0.18$. In the omnibus ANOVA, the main effects of *Response Set,* $F(1, 219) = 89.353$, $p < .001$, $\eta_p^2 = 0.290$, and *Order of Response Sets*, $F(1, 219) = 4.090$, $p = .044$, $\eta_p^2 = 0.018$, and the interaction between them were significant, $F(1, 219) = 48.325$, $p < .001$, $\eta_p^2 = 0.181$. Keypressing was generally faster than movement of the computer mouse, especially when keypressing was the first response set, but not when computer-mouse movement came first.

In a corresponding ANOVA of the (log-transformed) error rates, the main effect of *Consistency* was significant, $F(1, 219) = 30.699$, $p < .001$, $\eta_p^2 = 0.123$, with more errors in training-inconsistent trials ($M = 3.4\%$, $SE = 0.3$) compared to training-consistent trials ($M = 5.2\%$, $SE = 0.4$). The *Consistency $_x$ Response Set* interaction effect was not significant, $F(1, 219) = 2.486$, $p = .116$, $\eta_p^2 = 0.011$. Planned comparison revealed significant consistency effects in test blocks with keypressing (ΔMs = 1.3%; $t[220] = 3.321$, $p = .001$, $d_z = 0.22$) and mouse-movements (ΔMs = 2.1%; $t[220] = 4.659$, $p = .001$, $d_z = 0.31$). In the omnibus ANOVA, the main effect of *Response Set* (fewer errors with keypressing), $F(1, 219) = 11.208$, $p < .001$, $\eta_p^2 = 0.049$, the main effect of *Response Set Order* (fewer errors with keypressing as first response set), $F(1, 219) = 4.499$, $p = .035$, $\eta_p^2 = 0.020$, the two-way interaction effect between these factors (more keypress relative to mouse movement errors when keypressing was the first response set and vice versa when the mouse movement task came first), $F(1, 219) = 36.875$, $p < .001$, $\eta_p^2 = 0.144$, and the three-way interaction effect (larger consistency effect in keypressing than in mouse movements when keypressing was the first response set and vice versa when mouse movement was the first response task), $F(1, 219) = 9.176$, $p = .003$, $\eta_p^2 = 0.040$, were also significant.

Discussion

Study 2 examined whether the training-induced change in implicit response tendencies is larger in the absence of incongruent motor-action relations. The results did not reveal a difference between test conditions with incongruent S-R relations (keypress response set) and without competing responses on the action level (computer mouse response set). In fact, a training-induced consistency effect was observed with comparable magnitudes in both test conditions, which can be explained with stimulus-end relations that operate independently of S-R relations.

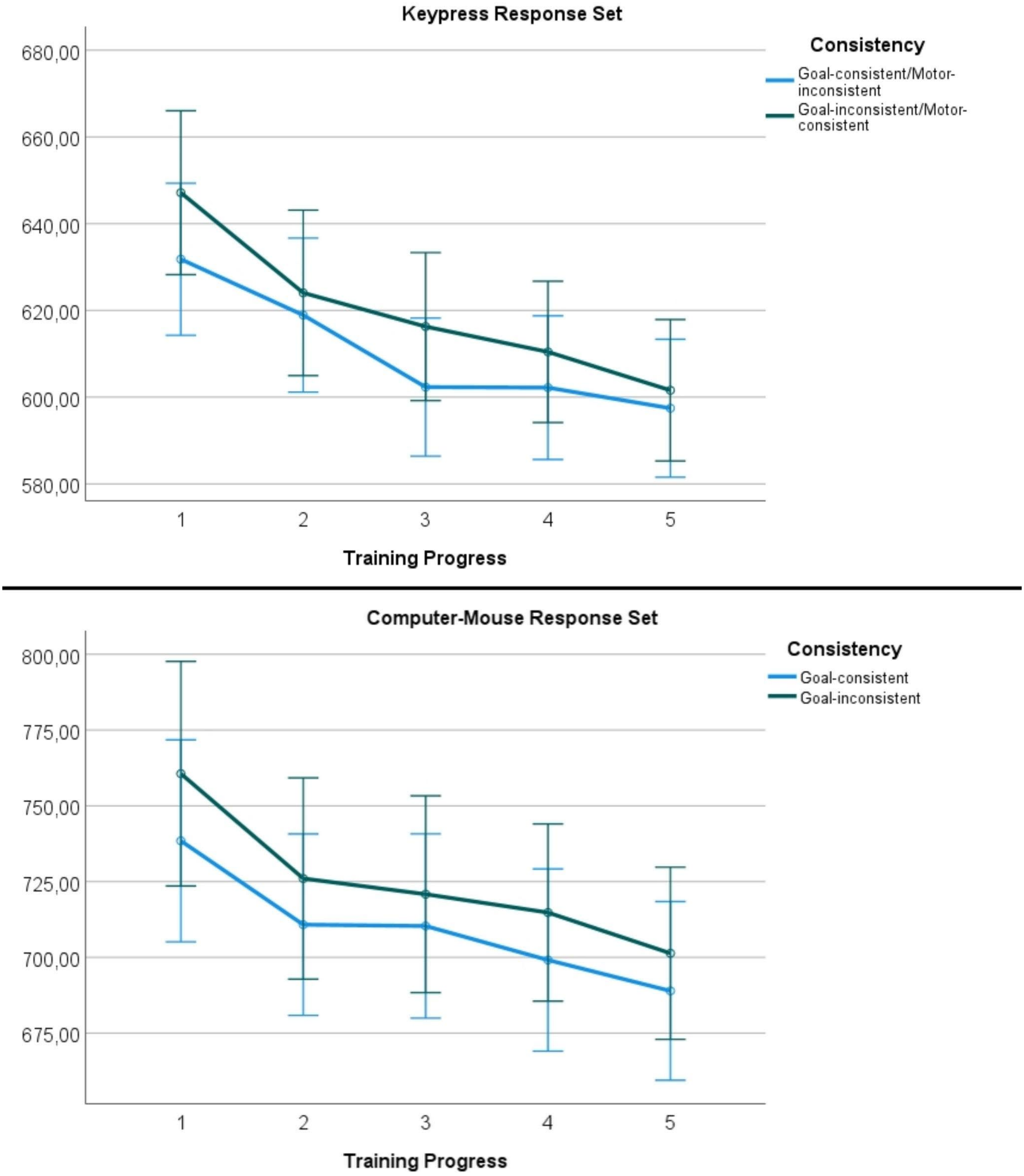


Fig. 3 Reaction times (in ms) in training-consistent and training-inconsistent trials with keypress responses or mouse movements as a function of training progress (test task blocks 1–5) in Study 2. Error bars show the 0.95 confidence interval. Note that the order of the response set conditions was counterbalanced across participants

Study 3

In our third experiment, we investigated whether trained stimulus-action relations in the AAT would be transferred to the test condition when the relationship between keypresses and manikin movement is the same during training and test. To this aim, we compared a test condition in which stimulus-action relations were identical with the AAT (SR-congruent condition) with a test condition in which the opposite response key must be pressed to trigger a goal-consistent manikin movement (SR-incongruent condition).

The SR-incongruent condition replicated the goal-consistent condition of Study 1 and motor interference condition in Study 2. Therefore, we expected to reproduce the result found in these study conditions (i.e., a goal-consistency effect). Furthermore, if stimulus-response associations contribute to the effect, the training-induced consistency effect should be greater in the SR-congruent condition (where stimulus-goal and stimulus-action relation trigger the same keypress response) than in the S-R incongruent condition (where the opposite response key must be produced to produce a training-consistent manikin movement).

Method

Participants

Sample size planning was the same as for Study 2. Data of $N = 215$ participants were collected online via the Prolific participant recruitment platform (payment excluding extra performance-based monetary reward: £2.00). Exclusion criteria on the participant level were the same as those for the previous studies. After exclusions, the final sample was $n = 199$ (87 females, 111 males, 1 other; M_{age} = 28.7 years, $SD = 8.7$). Informed consent was obtained from the participants and the study procedure was approved by a local ethics committee (see our Ethics Approval Statement).

Design and Procedure

The experiment was identical to Study 2 except that the mouse movement test condition was replaced by a keypress condition with a response set that was identical with that used for the training task: in this SR-congruent keypress condition, the manikin appeared at the same position as during the training task and the same keypresses used for the training steered the manikin towards or away from the word depending on the font style. In the SR-incongruent keypress condition, by contrast, the opposite key had to be pressed to steer the manikin in the instructed direction, as in the keypress conditions of the previous experiments. Half of the sample started with the SR-congruent and the other half with the SR-incongruent test conditions. After six AAT-test block pairs, the test condition switched.

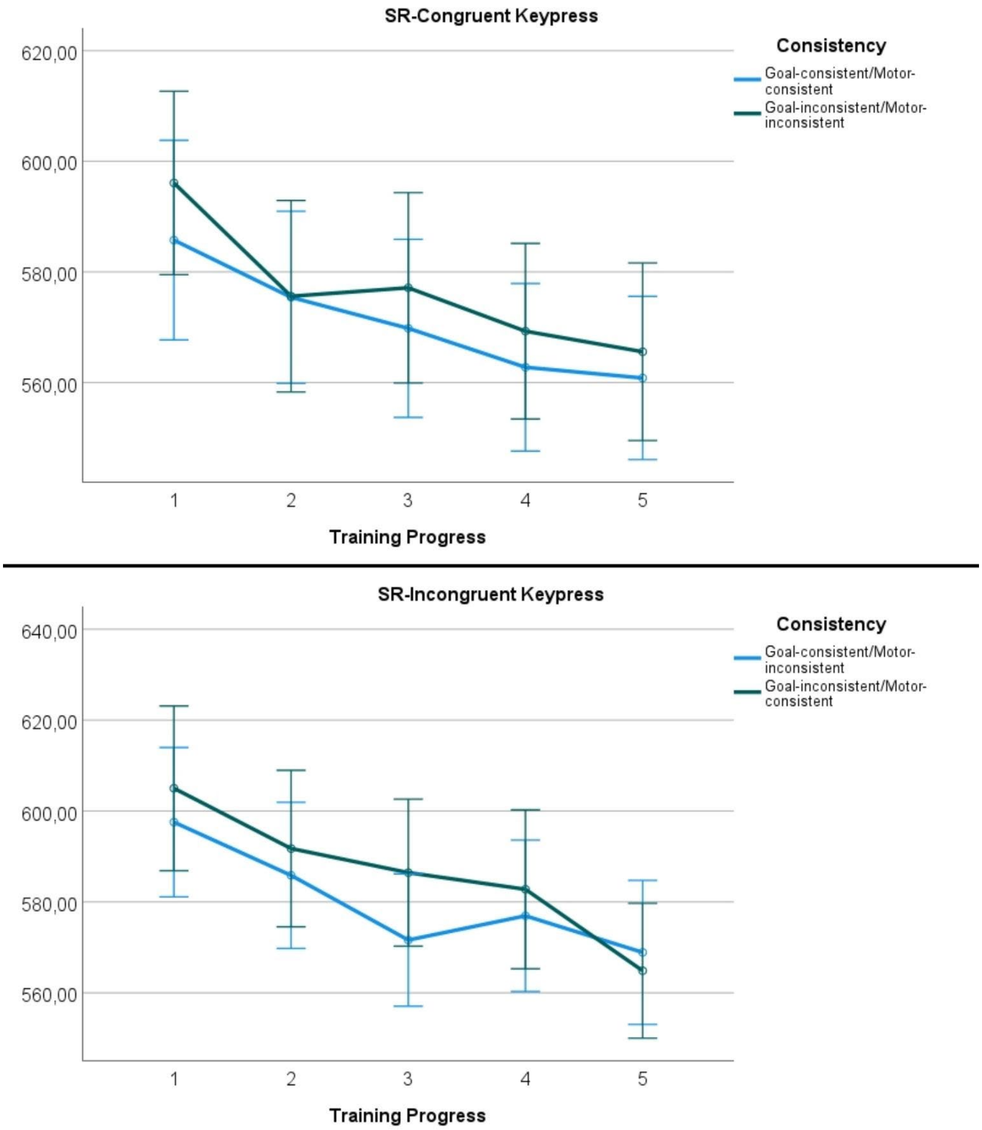
Results

Correct performance in the AAT task ($M = 96.5\%$, $SD = 3.8\%$) and in the goal-reminder trials ($M = 96.6\%$, $SD = 2.9\%$) was very high.

Reaction times in the test task were analysed with a mixed ANOVA with the factors *Consistency* (training-consistent vs. -inconsistent; within-subjects), *Response Set* (SR-congruent vs. SR-incongruent keypress; within-subjects) and *Response Set Order* (SR-congruent condition first vs. SR-incongruent condition first; between-subjects) as factors. The ANOVA produced a significant main effect of *Consistency*, $F(1, 197) = 19.374$, $p < .001$, $\eta_p^2 = 0.090$. Overall, reaction times were shorter in training-consistent ($M = 601$ ms, $SE = 6.9$) than training-inconsistent test trials ($M = 614$ ms, $SE = 7.2$) (see Fig. 4). The interaction between *Consistency* and *Response Set* was not significant, $F(1, 197) = 0.338$, $p = .561$, $\eta_p^2 = 0.002$. Planned follow-up comparisons confirmed a significant consistency effect in the SR-congruent test condition (ΔMs = 16 ms), $t(198) = 3.782$, $p < .001$, d_z = 0.268, and in the SR-incongruent test condition, (ΔMs = 12 ms), $t(198) = 3.066$, $p = .002$, d_z = 0.217. In the omnibus ANOVA, the two-way interaction effect between *Response Set* and *Order of the Response Sets* was also significant, $F(1, 197) = 83.775$, $p < .001$, $\eta_p^2 = 0.298$. Reaction times in the SR-congruent test condition were generally faster than those in SR-incongruent condition when the latter condition was presented first and vice versa when the former test condition came first. Other effects were not significant (largest F-value = 2.453, smallest p-value = 0.119).

A corresponding ANOVA of the (log-transformed) error rates corroborated the results of the RT analyses. The main effect of *Consistency* was significant, $F(1, 197) = 20.822$, $p < .001$, $\eta_p^2 = 0.096$, with fewer errors in training-consistent ($M = 1.9\%$, $SE = 0.2$) compared to training-inconsistent trials ($M = 3.4\%$, $SE = 0.3$). The two-way interaction between *Consistency* and *Response Set* was not significant, $F(1, 197) = 2.245$, $p = .136$, $\eta_p^2 = 0.011$. In follow-up tests, consistency effects were significant in the SR-congruent (ΔMs = 1.0%; $t[198] = 2.606$, $p = .005$, d_z = 0.19) and in the SR-incongruent test conditions (ΔMs = 1.7%; $t[198] = 4.072$, $p < .001$, d_z = 0.29). In the omnibus ANOVA, the *Response Set* $_x$ *Response Set Order* interaction effect, $F(1, 197) = 14.847$, $p < .001$, $\eta_p^2 = 0.070$, and the *Consistency* $_x$ *Response Set Order* interaction effect (larger consistency effect when the SR-incongruent condition was first), $F(1, 197) = 7.345$, $p = .007$, $\eta_p^2 = 0.036$, were also significant. Other effects were not significant (largest F-value = 2.364, smallest p-value = 0.126).

Fig. 4 Reaction times (in ms) in training-consistent and training-inconsistent trials with SR-congruent and SR-incongruent response sets as a function of training progress (test task blocks 1–5) in Study 3. Error bars show the 0.95 confidence interval. Note that the order of the keypress conditions was counterbalanced across participants



Discussion

Study 3 replicated the goal-consistency effect found in the previous experiments: performance was better when the action goal was consistent with the trained stimulus-action relation. The magnitude of the training effect was not influenced by whether the same or the opposite response key must be pressed to produce a training-consistent manikin movement, demonstrating that the stimulus-action relationship did not transfer to the test phase.

General Discussion

Three web-based experiments (total $N=514$) with samples from the general population examined whether a training to approach or avoid fictitious social groups changes action tendencies to approach or avoid these groups in an indirect measurement task. Results consistently demonstrated a training-induced response change: keypresses effecting movements of a symbolic manikin towards or away from the social groups were initiated faster and with less errors when the goal of manikin movement was consistent with the trained action goal to this group relative to a condition in which the goal was changed from training to test. Even more important, the magnitude of the AAT effect was not affected by whether the same, a different, or a training-inconsistent keypress was required to initiate the AA movement. Overall, these findings clearly demonstrate that a training of stimulus-goal relations, but not of stimulus-action relations, changes implicit response tendencies, at least with the present variant of AAT.

The finding that a training of stimulus-goal relations, and not of stimulus-action relations, affects AA tendencies has theoretical as well as practical implications. With respect to theoretical accounts of AAT effects, results are in line with explanations that deemphasize the role of a repeated pairings, or association formation, between stimuli and particular and highlight the role of relational knowledge acquisition during AAT phases. According to the inferential account (Van Dessel et al., 2019), AAT tasks serve the purpose to transmit knowledge about relations between specific stimuli and actions ("I approached Person X"), and the outcomes that is generated by the action ("I usually approach a person that I like"), which is used for inferential reasoning about the liking or attractiveness of training stimuli ("I like this person because I approached her"). This relational knowledge can be acquired even without behavioural training, for example, via verbal instruction (Van Dessel et al., 2015). Furthermore, the means that are used for approach and avoidance can be easily exchanged according to this account as long as they are not needed for inferential reasoning, or as in the present study, for cognitive action control in an indirect response task.

By contrast, associative learning accounts of AAT effects typically highlight the importance of repeated pairings for a change in mental associations (Friese et al., 2011; Sharbanee et al., 2014). According to this account, the training stimuli become associated with motivational orientations through the pairing with AA-related actions that are wired to these systems in a bidirectional fashion. After a sufficient number of pairings, the trained action operates as a connector between the training stimuli and the motivational orientation linked to the trained action. In the present study, however, response tendencies were not affected by whether the same or a different action was required, which shows that the trained action (keypress) was not a part of the hypothesized associative structure.

With respect to practical uses of AAT procedures, the present study underscores the importance of a training of stimulus-goal relations for a behaviour change. AAT tasks that highlight stimulus-goal relations as much as possible during the training should be more effective in producing a response change in comparison to tasks that often use ambiguous and multiply interpretable responses (Eder & Rothermund, 2008; Krieglmeyer & Deutsch, 2010). The standard AA manikin task is well suited to this aim because of the equifinality of the behavioural actions in this task. Specifically, the task instruction to use different, and sometimes even opposite response keys, to direct the manikin towards or away from the training stimuli highlights the relation between the training stimuli and AA-related action goals. The present study also showed that a low number of training trials can be sufficient for producing a significant training outcome. As shown by the block analysis of Study 1, response tendencies changed rapidly, and the training-induced change was not monotonically related to the number of training trials. Adding additional training trials had no incremental effect after knowledge about the stimulus-end relationship had been acquired.

The study also has limitations. One important limitation is the use of a symbolic manikin task with keypress responses that highlighted stimulus-goal relations to the participants. Stimulus-response relations could be more influential in other AAT tasks with "embodied" actions of approach and avoidance. There is an ongoing discussion which bodily movements have intimate links are to approach/avoidance motivations (Eder, 2023; Price et al., 2012). Previous AAT studies often used a joystick lever movement task involving arm flexion and extension for a training of approach/avoidance tendencies (e.g., Sharbanee et al., 2014), assuming a connection between arm flexion and approach and between extension and avoidance (Chen & Bargh, 1999). However, numerous studies found no difference in motivated action tendencies whether arm flexion or extension was used to approach or avoid, questioning this link (e.g., Bamford & Ward, 2008; Markman & Brendl, 2005; Seibt et al., 2008). Other research suggested an intimate link with whole-body movements in forward and backward directions. For example, Nuel and colleagues (2022) demonstrated that trained leaning forwards produced more favourable evaluations of social groups in comparison to leaning backwards. Furthermore, Eder and colleagues (2021) found that positive stimuli facilitated forward stepping and negative stimuli backward stepping, even when the forward step generated a retreat motion from the stimuli and the backward step an approach motion in a three-dimensional virtual environment. Notably, this behavioural priming effect was only observed with whole-body movements and not with manual pushing and pulling of a lever. Therefore, it is possible that AAT with whole-body actions is affected more strongly by characteristics of the trained movement. It should be noted, however, that we do not know of a specific (association) theory that would justify the hypothesis that associations to complex, multi-joint movements (e.g., whole-body movement) are formed more readily in comparison to simple behaviour (e.g., keypressing). Furthermore, the modification of motivational tendencies with training protocols that promote stimulus-goal learning may even be advisable from an applied perspective because, most typically, approach/avoidance behaviour must be tailored to the affordances of the situation (Eder & Hommel, 2013; see also Morasso, 2022). From this perspective, it is advisable to train relations between stimuli and approach/avoidance goals with simple behaviours (e.g., keypresses) that could serve as interchangeable mental tokens for situation-appropriate behaviours.

Another important limitation concerns the selection of the training outcome (i.e., a change in implicit response tendencies). AAT studies often investigated changes in evaluative reactions or consumptive behaviours as training outcomes and it is possible that stimulus-action relations have a larger impact on these training outcomes. Albeit it is possible to combine several outcome measures in a single study design (see e.g. Sharbanee et al., 2014), interpretation of these measurements is not without problems because the intermixing of an indirect response measurement task (the test task) changes contingency relations between stimuli, action, and action goals during the training. Therefore, and due to pragmatic concerns (increased study length, higher study costs, etc.), we did not include additional training outcome measures (e.g., evaluative group ratings) in the present study. However, unpublished experiments from our laboratory using the training protocol from Study 1 confirmed that this AAT procedure is in principle effective in producing training-consistent evaluative changes in implicit and explicit liking measures. Hence, worries that the present findings could not be generalized to paradigms with other outcome measures appear to be unjustified.

A third limitation concerns our use of fictitious social groups as training stimuli that had little meaning or relevance for the participants. The use of unfamiliar stimuli for training has the benefit of providing tight experimental control over participants' knowledge of the stimuli. However, investigations of changes in an approach bias often used stimuli that were motivationally relevant and familiar to the participant (e.g., alcohol- or tobacco-related stimuli). There is an ongoing discussion whether AAT outcomes are different with relevant stimuli that involve a modification of preexisting attitudes and/or action inclinations (see e.g., Krishna & Eder, 2019; Mertens et al., 2020). Hence, future research should examine whether stimulus-response relations are more influential for the retraining of a preexisting response bias linked to specific motivational stimuli and particular groups (Loijen et al., 2020).

AAT protocols also differ in respect to whether they direct attention to the contingency between the training stimuli and the approach/avoidance responses. In the present research, group membership was the relevant stimulus feature for the approach-avoidance training which became irrelevant only for the test task. In other AAT studies, in contrast, participants were often trained to approach/avoid stimuli without directing attention to the contingency with specific stimulus features. For example, participants in the alcohol-avoid study of Sharbanee et al. (2014) responded to the orientation (landscape vs. portrait) of alcohol-related pictures and not to whether the picture showed an alcoholic beverage. Hence, the relationship between the stimulus feature of interest for the training (here: alcohol) and the contingent AA response was not disclosed to the participant, which could have affected stimulus-action learning. From what is known about association formation, however, directing *less* attention to the relationship between a stimulus feature and its contingent response suppresses, rather than promotes, associative learning in humans (for a review see Le Pelley et al., 2016). In fact, Van Dessel and colleagues obtained AAT effects only when participants were aware of the trained stimulus-action contingencies (Van Dessel et al., 2016; Van Dessel et al., 2016b). Hence, it is not plausible that the use of a direct feature training task in the present research has inhibited the formation of stimulus-response associations.

To sum up, the present research demonstrates that, after a web-based training to approach and avoid members of two fictitious social groups, samples from the general population learned to associate the social group members with AA- related action goals and not with the motoric action in the service of the goal. A transfer on the goal, but not on the motor level, is in line with inferential accounts of AAT effect and challenging to associative accounts. Furthermore, a transfer on a relatively abstract AA goal level supports claims that AAT procedures could be used for a modification of AA-related behaviour that is different from the trained behaviour in the laboratory.

Author Contribution AE developed the study concept. Both authors contributed to the study design. AK programmed the experiments. Data were collected by research assistants supervised by AK. AE performed the data analyses and drafted the manuscript. AK provided critical revisions.

Funding Open Access funding enabled and organized by Projekt DEAL.

Data Availability Preregistration documents, experiment files, and raw data can be accessed at https://osf.io/5rt4u/.

Declarations

Conflict of Interest This research was supported by grants Ed201/3 – 1 and Ed201/3 – 2 of the German Research Foundation (DFG) to Andreas Eder. The funding agency had no role in the study design, collection, analysis, or interpretation of the data, writing the manuscript, or the decision to submit the paper for publication.

Ethics approval and consent to participate The study was performed with human subjects in accordance with the ethical standards as laid down in the 1964 Declaration of Helsinki and its later amendments and the study procedure was approved by the ethics committee of the University of Würzburg, Department of Psychology (reference no. GZ 2018-22).

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