Habit Formation and Multiple Means to Goal Attainment: Repeated Retrieval of Target Means Causes Inhibited Access to Competitors

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Three studies examined the cognitive processes underlying the formation of goal-directed habits in a multiple means context. Repeated retrieval of target means upon goal activation was expected to result in inhibition of competing means for the same goal. In all studies, participants studied goal–means combinations and subsequently practiced the retrieval of certain means to attain the goals in a retrieval paradigm. Study 1 tested accessibility of the different means in a goal–means verification task and showed that competing means were not inhibited after a single retrieval but only upon repeated retrieval (three or nine times). Studies 2 and 3 extended these findings in a means–recognition task and demonstrated that inhibition occurred in the absence of explicit intent or instructions to suppress the competitors. These inhibitory effects of competing means are discussed against the background of current social cognition research on the processes underlying goal–means networks and the formation of habits.

Keywords: *inhibition; habit formation; memory retrieval; goal–means network; multiple means context*

Most human beings are fortunate to possess a mental system that allows them to find appropriate means in memory for attainment of their goals. Through practice and repetition, we are capable of swiftly initiating and performing our goal-directed behaviors in a routine fashion. Thus, when having dinner at one's favorite restaurant, one may order ice cream instead of fruit salad for dessert without much conscious thought. Habit formation, then, allows people to readily retrieve and select a specific means from a set of different means in memory to pursue a specific goal.

The way people retrieve means from memory to attain goals in the course of forming habits is a fundamental concern in both basic and applied psychology (Betsch, Haberstroh & Höhle, 2002; Cooper & Shallice, 2000; Moskowitz, Li, & Kirk, 2004). Most previous research on (habitual) goal pursuit has focused particularly on the retrieval and selection of a certain means for goal attainment (Aarts & Dijksterhuis, 2000; Bargh, 1990). More recently, researchers have started to examine the role of *inhibitory* processes in goal pursuit (Mayr, 2002; Shah, Friedman, & Kruglanski, 2002). Inhibition is argued to be a functional mechanism that reduces or prevents interference of accessible competing information and to shield current goal pursuit from distraction. However, less is

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known about inhibitory processes during the formation of goal-directed habits in a multiple-means context. Studying inhibitory processes as part of habit formation is crucial to understanding how people are able to choose between multiple means to pursue their goals in a routine fashion without much attentional effort. It may lead to a better understanding of how habits are established and, in the end, how they are maintained.

In this article we investigate the cognitive process guiding the first stage of the habit-formation process in a multiple-means context. We assume that the inhibition of competing means eases the retrieval of target means and thus promotes the formation of goal-directed habits. Specifically, the retrieval and selection of target means upon goal instigation becomes more efficient when the associated competing means are inhibited before these competitors come to mind. Our purpose is to investigate some key assumptions derived from this conceptualization. First, we hypothesized that retrieval of a target means upon goal activation results in inhibited access to the competing means. Second, we assumed that this inhibitory control requires some practice and can emerge implicitly, that is, without conscious intent or explicit instructions to do so.

GOAL–MEANS NETWORK

For goal activation to have the desired effect, behavior representations need to be retrieved and accessed that represent appropriate means to attain the goal (Aarts & Dijksterhuis, 2000; Austin & Vancouver, 1996; Wegner & Vallacher, 1986). Often goal attainment can be realized with the use of different mutually exclusive means, also called the principle of equifinality (Kruglanski et al., 2002); for example, bicycle and car may both be appropriate means for (and therefore associated with) the goal of traveling to work. According to the goal system theory of Kruglanski and colleagues (2002), goals and their associated means are part of a knowledge network, and this network consists of facilitative and inhibitory connections. There is some recent research that shows how goals and means are related to each other and how these relations affect the accessibility and selection of means for goals (Aarts & Dijksterhuis, 2000; Kruglanski et al., 2002; Moskowitz et al., 2004).

According to the goal system theory (Kruglanski et al., 2002), the connection between a goal and the associated means is facilitative, but the connection between two means can also be inhibitory. The facilitative link between a goal and means indicates that activation of the goal facilitates access to the associated means, whereas the inhibitory link between the means suggests that the activation of one means inhibits access to the other competing means. This suggests that before a competing means is inhibited, it is first activated by the instigation of the goal. Hence, inhibition is an active process between the means. For example, one may consider bicycle and car as two competing means for work travel (unless one can cycle and drive a car at the same time). In case one wants to take the bicycle to go to work, car use interferes with the retrieval of the bike. Hence, the mental accessibility of the car may be inhibited when retrieving the bike upon the activation of the goal of traveling to work.

There is some recent research showing the role of inhibitory processes in reducing or preventing interference of accessible competing behavioral information in the course of goal pursuit (Mayr, 2002; Shah et al., 2002). Shah and colleagues (2002) conducted research to examine inhibitory processes in the face of multiple competing goals. They asked participants to list several different goals (e.g., running, biking). Subsequently, accessibility of these goals was assessed under conditions of priming either one of these goals. Priming with one goal resulted in inhibited access to the other goal. They explained their results as a goal-shielding effect that prevents competing goals from interfering. Shah et al. reasoned that the goals were part of a network in which they also served as subgoals to achieve an overarching goal (e.g., the goal of exercising). Priming one of the subgoals was assumed to activate the entire goal network. Consequently, the competing remaining subgoals were inhibited to shield the focal subgoal from distraction to attain the hypothesized overarching goal, as was concluded from the delayed response latencies on these subgoals. It is important to note, however, that they did not investigate this process directly. That is, inhibition of subgoals was not tested in the context and presence of the goal–means network under investigation.

This research aimed to take a closer look at this issue. Specifically, we investigated the role of inhibitory processes during the initial stage of the formation of goal-directed habits. Accessibility of the competing means was therefore tested as a function of the frequency of retrieving target means for goals.

INHIBITION AND THE FORMATION OF GOAL-DIRECTED HABITS

Habits have been known to play a pivotal role in human behavior. For instance, James (1890) considered habits to be extremely useful; they enable people to perform their actions in a mindless fashion, thereby creating more room for doing things that necessarily require conscious processing. Furthermore, the concept of habit has been central in behaviorists' approaches to learning theories (e.g., Hull, 1943; Skinner, 1938; Watson,

1914). In this approach, habits are thought to be guided by well-learned stimulus–response combinations that are reinforced by positive rewards. Behavior, therefore, consists of habitual responses that are automatically initiated upon the presence of the environmental cues and as such are rigid behavioral patterns that do not need top-down–driven processes. The automatic and rigid nature of habits has remained a central assumption in several contemporary areas of research, such as social psychology (e.g., Bentler & Speckart, 1979; Neal, Wood, & Quinn, 2006; Ouellette & Wood, 1998) and (neuro)cognitive analyses of human as well as animal behavior (e.g., Balleine & Dickinson, 1998; Botvinick & Plaut, 2006). For instance, Ouellette and Wood (1998) showed that cognitive products of reasoning and conscious thought, such as intentions, do not predict behavior when the given behavior is well practiced (see also Aarts, Verplanken, & van Knippenberg, 1998).

Building on recent work in the domain of social cognition and automatic goal pursuit (Aarts & Dijksterhuis, 2000; Bargh, 1990; Moskowitz et al., 2004), in this article we examine the cognitive processes underlying the role of habits in goal-directed behavior. Specifically, we conceive of habits as being guided by mental representations of goal–means associations. According to this view, habit formation occurs when the same means is repeatedly and consistently retrieved for the same goal because it promotes an automatic search for and access to these means in memory (cf. J. R. Anderson, 1993; Mäntylä, 1993). Once a habit is formed, the instigation of the goal results in the immediate retrieval and selection of the associated habitual means. However, to form a habit and in the end to arrive at the automatic retrieval of the habitual means, one needs to avoid interference from distracting means that are also suitable for goal attainment (Cooper & Shallice, 2000; Kuhl & Beckmann, 1985; Shah et al., 2002).

Inhibition helps to avoid the interference by reducing the activation of the competing means before these means become accessible (for a broader discussion on the functionality of inhibition processes see, e.g., Dagenbach & Carr, 1994; Dempster & Brainerd, 1995). That is, inhibitory control is necessary for memory retrieval to override prepotent memories or, more specifically, to prevent the mental representations of competing means for goal attainment to gain access to consciousness (M. C. Anderson, 2003; Moskowitz et al., 2004; Radvansky, 1999). Hence, inhibitory control is assumed to emerge implicitly, that is without conscious intent or explicit instructions to strategically suppress the competing information (Levy & Anderson, 2002; see also Dijksterhuis & van Knippenberg, 1998, for a distinction between implicit inhibition and explicit suppression). In the context of habit formation in a multiple-means context, the inhibition of competing means for goal attainment is likely to require repetition because the inhibitory link between the means needs to be created in the memory system (Chan, Morell, Jarrard, & Davidson, 2001; Davidson, Kanoski, Walls, & Jarrard, 2005; Shah et al., 2002). How, then, may this practice process evolve during habit formation?

In line with others, we assume that the initial instigation of the goal will activate all associated means (e.g., Altmann & Trafton, 2002; Kruglanski et al., 2002), which enables people to select one of these means to attain the goal. Subsequent instigation of the goal increases the probability of retrieving the target means previously selected but, at the same time, activates the competing means that hinder the retrieval of the target means. A more efficient retrieval of this target means, then, is possible when the activated competing means are inhibited before these competitors gain access to consciousness. Accordingly, the potential interference of competing means can be resolved by establishing an inhibitory link in the memory system between the several means. This inhibitory link paves the road for practicing the inhibition of the competing means to promote the formation of goal-directed habits. According to this line of reasoning, inhibition of competitors is not likely to occur after a one-time retrieval of a target means, but inhibition should show up upon subsequent retrieval of the target means for the goal. In other words, repeated retrieval of a target means upon goal activation results in inhibited access to the competing means.

THE PRESENT RESEARCH

In a first attempt to investigate these ideas, three studies tested the inhibition of competing means as a function of repeated retrieval of a target means upon goal activation. To gain insight into the frequency component, we manipulated the number of times the target means had to be retrieved: one time, three times, or nine times. We expected inhibition to occur only after repeated retrieval, that is, after participants retrieved three or nine times the target means upon goal instigation. To test our prediction, we adapted the Retrieval-Induced Forgetting (RIF) paradigm developed by M. C. Anderson and colleagues (M. C. Anderson & Spellman, 1995). This paradigm is designed to examine the influence of memory retrieval of category items on other competitive items associated with the same category (see also M. C. Anderson, 2003, for an overview of research using the RIF paradigm in a variety of domains). We adjusted the RIF paradigm with the aim of investigating the influence of (repeatedly) retrieving certain means from memory upon goal activation on the accessibility of competitive means for the same goal. In

line with the RIF paradigm, our experiments consisted of three distinct phases: a study phase, a retrieval phase, and a test phase.

In the study phase, participants have to study several goal–means combinations (e.g., wanting to chat—computer and telephone, wanting a dessert—fruit salad and ice cream) to establish instrumental associations between the means and the specified goals and to create goal networks with two unique means strongly associated to one goal. In the retrieval phase, participants are asked to retrieve some of the given means to pursue some of the specified goals by using a cued-stem completion task (wanting to chat–co_). Because our main research question was how the process of repeated retrieval of target means for goal attainment influenced the accessibility of competing means, we experimentally varied the frequency of retrieving the target means between participants: either one, three, or nine times. This phase thus simulates the retrieval and selection of target means upon goal activation. During the retrieval phase three distinct types of means are created: retrieved means (computer), nonretrieved means (telephone) for the same goal (wanting to chat), and nonretrieved baseline means (fruit salad, ice cream) for a different goal (having dessert).

The final phase of the experiment tests the accessibility of the different means. Inhibition of a mental concept is defined as a reduction in the activation level of that concept. In line with other research using the RIF paradigm, we assessed accessibility of the different means by using different reaction time tasks (see also Perfect, Moulin, Conway, & Perry, 2002; Veling & van Knippenberg, 2004). Evidence for inhibited access to competing means, then, is established if the accessibility level of the nonretrieved means for the same goal is lower (responses to these concepts are slower) than the accessibility of the nonretrieved means for a different goal. The first two studies examined the inhibition of competing means as a function of repeated retrieval by assessing their mental accessibility in a goal–means verification task (Study 1) and a means recognition task (Study 2). A third study explored the idea that the inhibitory control occurs implicitly.

STUDY 1

In the first experiment a verification task was used in which participants were briefly presented with a goal (e.g., wanting to chat) and immediately asked to indicate whether a subsequent presented means (e.g., computer or telephone) is a means to pursue that goal. Responses on this task thus rely on the mental link between the means and the specified goal (Aarts & Dijksterhuis, 2000). The rationale we followed here was that the stronger a nonretrieved competing means is inhibited as a function of previous retrieval of the target means upon goal activation, the slower the responses to verify that the nonretrieved competing means is a possible means for attainment of the goal (Perfect et al., 2002). To conclude that the access to the means is inhibited, however, a comparison has to be made with a proper baseline.

In a standard RIF experiment, the baseline means are not activated during the retrieval phase because participants are not exposed to the goals related to these means. As a consequence, the memory traces between these goals and their associated means will not render active. However, this may pose a problem to observe inhibition in the goal–means verification task (i.e., test phase). Both the retrieved target means and nonretrieved competing means will have an advantage in the verification task because of the recent activation of their memory trace with the goal in the retrieval task (the goal activates both means upon which the competing means is inhibited) in contrast to the baseline means. Activation of the goal in the subsequent verification task is more likely to activate the associated retrieved target means and nonretrieved competing means in comparison to the baseline means. Consequently, reaction times on the competing and baseline means might be equal because slower responses to the nonretrieved competitors because of inhibited access are elevated by the recent activation of their memory trace. Accordingly, one could incorrectly conclude that no inhibition occurred.

To control for this potential memory-trace advantage, another baseline condition was included in addition to the standard baseline condition. In this condition, half of the baseline goals were also presented in the retrieval phase, thus activating the memory trace between the baseline goals and their associated means (J. R. Anderson, 1983; Mäntylä, 1993). However, these means do not require retrieval (no cued-stem completion is required upon goal presentation), and therefore, we call this condition the mere exposure baseline. Accordingly, these means should have the same memory-trace advantage in the verification task as the retrieved-target means and their nonretrieved competitors. Comparing the response latencies on the means from the retrieval condition with the means from the mere exposure baseline condition, then, is expected to provide a fairer test of facilitated access to the target (retrieved) means and inhibited access to competing (nonretrieved) means.

Method

Participants and Design

One hundred twenty-four Dutch undergraduates received €5 payment for their participation in the

experiment. Participants were randomly assigned to one of the three retrieval-frequency conditions: one, three, or nine times.

Stimulus Material

We selected 12 goals, each goal combined with two competing means, resulting in 24 different goal–means combinations. Each goal attribute represented a behavior (e.g., writing, relaxing) and each means represented an object (e.g., computer, television). The selection of the goal–means combinations was based on a pilot study that assessed the associative strength and perceived instrumentality of the goal–means combinations. Only goal–means combinations were selected that showed clear instrumentality but moderate association strength. This was done to ensure that their association could be strengthened in the study phase (see below), rendering the instrumental relations between the goal and means unique for the present experiment.

Procedure

Participants worked in separate cubicles on the experimental computer task. The computer provided all the instructions. Participants were told that the experiment consisted of several tasks that dealt with the pursuit of everyday goals by using all kinds of means. Therefore, participants were explicitly instructed to think in terms of the instrumental relation between goals and means (see also Shah et al., 2002). Next, participants worked on three consecutive tasks representing the phases of the RIF paradigm: the study phase, the retrieval phase, and the test phase.

Study phase. The first phase of the experiment consisted of a task in which all the goal–means combinations were studied. Every combination was presented for 7 sec followed by a 1-sec pause. Participants were asked to carefully study the competing goal–means combinations and to consider each of the two means sufficient to attain the goal. All the goal–means combinations were shown once. To make sure that two means associated to the same goal were not shown one after the other, two blocks were created. The first block consisted of the 12 goals connected to one of the means, and the other block consisted of the same 12 goals connected to the other means. Before, between, and after the blocks, two filler goal–means combinations were used to prevent primacy and recency effects from occurring. The order of the blocks was counterbalanced between participants, and within each block the goal–means combinations were chosen randomly.

Retrieval phase. After studying the goal–means combinations, participants were told that they would be shown some of the goals from the study task and that they had to imagine pursuing these goals using one of the means. On some trials the goal was presented together with one of the instrumental means they were supposed to use to attain the goal, and on other trials only goals were presented. To increase the feeling of means retrieval, it was told that on trials where the goal was presented with the means, only the first two letters of that means would be displayed. Accordingly, the participant's task was to complete each means by typing in the remaining letters. On each trial the goal was presented briefly (500 ms), followed by a pause (50 ms) and the presentation of the two letters of the means on some trials and on other trials not (these were the mere exposure baseline goals). The time to complete each means was limited to 5 sec and, when the correct answer was provided, the screen went black until the 5 sec passed, after which the next trial was displayed. Participants were told that if the answer was incorrect, the goal and two letters of the means would be presented again until the answer was correct or the time ran out. In the one-time retrieval practice condition, six different goal–means letters combinations and three different exposure baseline goals were presented once. In the three-times retrieval practice condition this presentation procedure was repeated three times, and in the nine-times retrieval practice condition this procedure was repeated nine times.

To ensure that each means from the study phase would serve as a retrieved means, a nonretrieved competing means associated to the same goal and a baseline means (standard and mere exposure), different sets were created that varied the function of the means. These sets were counterbalanced between participants. Within every retrieval round, the presentation order of the goals and goal–means letters was random and presented once. Thus, after the retrieval phase, 4 different categories of means were created that each included 6 means: retrieved means, nonretrieved competing means associated to the same goal, baseline means of which only goals were presented (mere exposure), and baseline means of which nothing was shown (standard).

Test phase. In the final phase of the experiment, participants had to perform the goal–means verification task. The task consisted of 48 goal–object combination trials. Each trial started with a fixation cross appearing in the middle of the screen (500 ms), after which the goal word was presented (200 ms), a pause (100 ms), and finally an object. Participants had to indicate as fast as possible whether the object represented a means instrumental for attaining the goal by pressing a "yes" or "no" key on the keyboard. The object remained on the screen until participants pressed a key. Response times were measured in ms. The intertrial time was 1 sec. The 48 trials consisted of the 24 goal–means combinations from the study phase, and 24

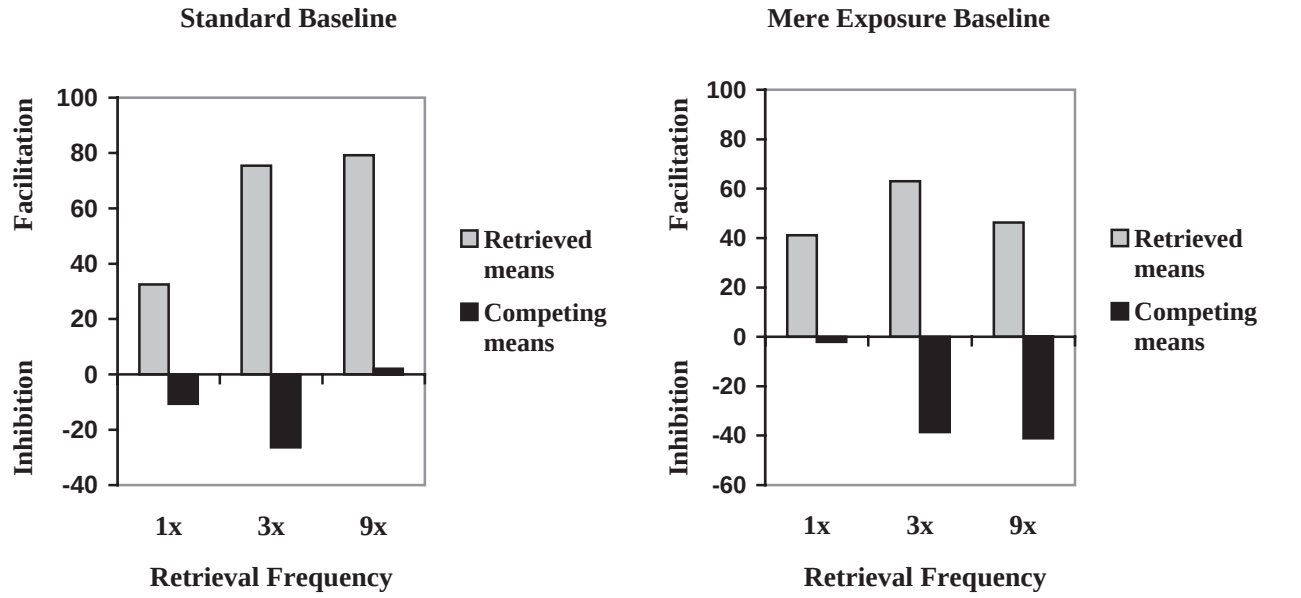

Figure 1 Mean difference scores in reaction time (ms) on the retrieved and competing means with the baseline means per retrieval frequency. The reaction times are presented separately for each type of baseline (analyses with the standard baseline are represented in Figure 1a and with the mere exposure baseline in Figure 1b). In both graphs, a positive score indicates facilitation, and a negative score indicates inhibition.

new goal–means combinations for which the means was not instrumental for attaining the goal (e.g., wanting to chat—sandwich). This way, 24 goal–object combinations required a yes response, and 24 goal–object combinations required a no response. No new goals were added in the task, so only goals from the study phase were presented. Participants did not know in advance which and how many goal–object combinations would be presented. Prior to the 48 trials, 4 warm-up trials were presented. The 48 goal–object combinations were presented randomly.

Results

Retrieval Percentage in Retrieval Phase

To assess whether participants retrieved the means to the same extent in the different retrieval-frequency conditions, the responses on the retrieval task were scored and the mean proportion of retrieved means was calculated. Participants were quite successful in retrieval of the means; the overall rate was 87%. There was no effect of retrieval frequency, $F < 1$.

Test Phase

Trials on which participants indicated that the objects from the 24 goal combinations from the study phase were no means to attain the goal (nearly 6% of the trials) as well as reaction times higher than three times the standard deviation above the mean (2% of the trials) were excluded from the analyses on the reaction times.[1] Because two different baselines were used, the data are analyzed and reported separately for each baseline.

Standard Baseline

Reaction time. The response latencies were subjected to a 3 × 3 mixed model analysis of variance (ANOVA) with type of means (retrieved, standard baseline, and nonretrieved competing means) as the within-participants factor and retrieval frequency (one, three, or nine times) as the between-participants factor. This analysis yielded a main effect of type of means, $F(2, 242) = 29.73$, $p < .001$. Simple comparison tests showed that participants responded faster to the retrieved means compared to the baseline means, $F(1, 121) = 39.52$, $p < .001$. However, participants were not slower to the nonretrieved competing means than the baseline means, $F(1, 121) = 1.11$, *ns*, suggesting that the nonretrieved competitors were not inhibited. Figure 1a displays the response latency difference scores between the retrieved and standard baseline means and between the nonretrieved competing and standard baseline means for the three retrieval-frequency conditions separately.

According to our hypothesis, inhibition of the nonretrieved competitors is only assumed to occur after

repeated retrieval of the target means (after three and nine times) and not after the initial retrieval (one time). To test this specific hypothesis, we examined the contrast of the inhibitory effects in the one-retrieval practice condition against those in the three- and the nine-retrieval practice conditions together (in weights: –2, 1, 1, respectively). No effects were found, Fs < 1, *ns*. Furthermore, inhibited access was hypothesized to be found equally in the three- and nine-times retrieval practice conditions. The pattern in Figure 1a seems consistent with our hypothesis. To examine this specific prediction on inhibition after repeated retrieval, simple main effects were computed in which the differences in latencies between the nonretrieved competing means and the standard baseline means were examined separately for each retrieval-frequency condition. The analyses showed no inhibitory effect in any of the conditions, all Fs < 2, *ns*.

In sum, with a standard baseline, no clear inhibition effects were found on the competitors, whereas a strong facilitation effect was found on the retrieved means.

Mere Exposure Baseline

To reiterate, with the mere exposure baseline condition we tried to control for memory-trace advantages of the retrieved and nonretrieved competing means in the verification task. Accordingly, we again subjected the response latencies to a 3 × 3 ANOVA. Figure 1b displays the response latency difference scores between the mere exposure baseline means and the retrieved means on the one hand and the nonretrieved competitors on the other for the three retrieval-frequency conditions separately. As with the standard baseline, the analysis yielded a main effect of type of means, $F(2, 242) = 27.55$, $p < .001$. Simple comparison tests revealed that participants responded faster to the retrieved means compared to the mere exposure baseline means, $F(1, 121) = 25.77$, $p < .001$. It is more important to note (and in contrast with the standard baseline) that analyses showed that participants responded *more slowly* to the nonretrieved competing means than to the mere exposure baseline means, $F(1, 121) = 6.16$, $p = .01$, indicating that, overall, the competitors were inhibited.

Again, the pattern in Figure 1b appears consistent with the notion that inhibited access to nonretrieved competing means only emerges when participants retrieve the target means more frequently. To test our specific hypothesis that inhibition should only be found after repeated retrieval and no difference should be found between the three- or nine-retrieval practices, we tested the contrast of the inhibitory effects in the one-retrieval practice condition against those in the three- and the nine-retrieval practice conditions together (in weights: –2, 1, 1, respectively). Although marginally significant, $F(1, 122) = 2.72$, $p = .10$, the results suggest that inhibition only occurred when the target means was repeatedly retrieved for the goal (the inhibitory effect did not differ between the three- and nine-times retrieval practice conditions, $F(1, 122) = 0.02$, *ns*). We conducted simple comparison tests to examine the difference between nonretrieved competing means and mere exposure baseline means for each retrieval-frequency condition separately. These analyses revealed that the one-time retrieval practice did not inhibit the competing means, $F(1, 123) = 0.01$, *ns*, whereas three- and nine-times retrieval practices inhibited these means, $F(1, 123) = 3.82$, $p = .05$, and $F(1, 123) = 4.68$, $p = .03$, respectively.

Discussion

The results of the first experiment provide tentative evidence that access to the competitors was only inhibited after repeated retrieval of the target means. A single retrieval did not inhibit the competing means but repeated retrieval of the target means did cause inhibited access to the competing means. Inhibition did not decrease with further repetitive retrieval: No inhibitory difference was found between three- and nine-retrieval practices of the target means for the goal.

The findings of Study 1 were obtained by employing a goal–means verification task. Responses on this task partly rely on the association between the means and the specified goal. Because of this association aspect of the task, we had to control for memory traces in the retrieval task to observe inhibition of the competing means. To provide further support for our ideas, Study 2 aimed to replicate and extend the inhibitory findings by using a different accessibility measure that does not rely on association between goals and means. For this purpose, in Study 2 we used a means-recognition task to measure the speed of retrieving the means from memory (Veling & van Knippenberg, 2004). A recognition task assessed the unique accessibility status of the means during testing, thereby excluding the memory trace advantage of goal–means links resulting from the retrieval phase. Accordingly, only the standard baseline condition was used.

STUDY 2

Method

Participants and Design

One hundred thirty-five Dutch undergraduates received €5 in return for their participation. Participants were randomly assigned to one of the following three retrieval-frequency conditions: one, three, or nine times.

Material and Procedure

The materials, instructions, and procedure were similar to those used in Study 1, but with a few changes. In this experiment a means-recognition task was used in the test phase to measure the accessibility of the means studied in the study phase. Furthermore, 18 goal–means combinations were presented in the study phase: nine goals each associated to two means. In this phase, two blocks were again created, and in each block the nine goals were presented with one of the means. Before, between, and after the two blocks, two filler goal–means combinations were used to prevent primacy and recency effects from occurring. After the retrieval phase, which was also similar to the one used in Study 1, three different categories of means were created that each included six means: retrieved means, nonretrieved competing means, and (standard) baseline means. Again, participants had to complete the two-letters means string within 5 sec in the retrieval phase, and the same rules and instructions applied as in the first experiment. The baseline means were the nonretrieved means of the goals that were not presented during the retrieval phase.

The final phase of the experiment consisted of a means-recognition task in which participants had to indicate as fast and as accurately as possible whether the presented object was a means they had previously studied in the experiment. The faster participants were able to recognize the means, the more accessible the means were. In total, 36 objects were presented. The 18 objects from the study phase provided the "yes" answers, and 18 different objects not presented in the study phase provided the "no" answers. All objects were presented randomly, preceded by four warm-up trials.

Results

Retrieval Percentage in Retrieval Phase

We assessed whether participants retrieved the means to the same extent in the different retrieval-frequency conditions. The mean proportions of accurate retrieval showed that participants were very accurate in retrieval of these means; the overall retrieval rate was 95%. No differences in retrieval success were found between the different retrieval-frequency conditions, $F < 2$, *ns*.

Test Phase

Reaction time. Incorrect recognition responses (the number of accurate recognition was reasonably high: 80%) as well as reaction times higher than three times the standard deviation above the mean (2% of trials) were excluded from the analyses.[2] The analyses consisted of an 3 × 3 mixed model ANOVA with type of means (retrieved, baseline, and nonretrieved competing means) as the within-participants factor and retrieval frequency (one, three, or nine times) as the between-participants factor. Figure 2 shows the response latency difference scores between the baseline means and the retrieved means on the one hand and the nonretrieved competitors on the other for the three retrieval-frequency conditions separately. A main effect of type of means was found, $F(2, 234) = 61.97$, $p < .001$. Simple comparison tests showed that, overall, participants recognized the retrieved means faster than the baseline means, $F(1, 117) = 120.99$, $p < .001$. Also, an inhibition effect was found, $F(1, 117) = 4.23$, $p = .04$; participants recognized the competing means more slowly than the baseline means.

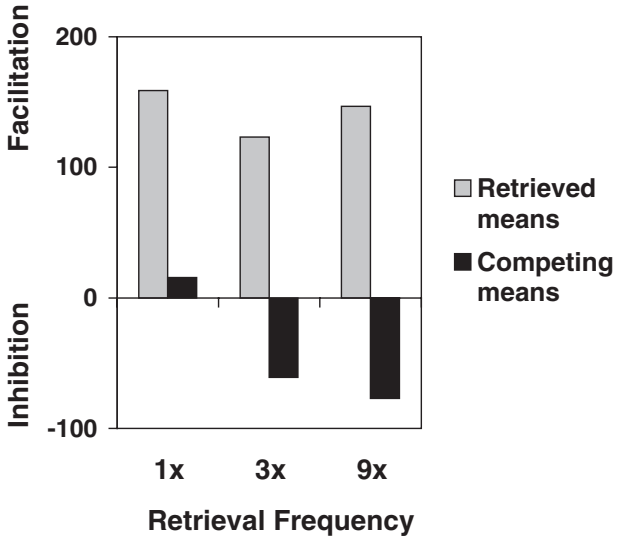

Figure 2 Mean difference scores in reaction time (ms) on the retrieved and competing means with the baseline means per retrieval frequency. A positive score indicates facilitation, and a negative score indicates inhibition.

Similar to Study 1, the pattern in Figure 2 suggests that nonretrieved competitors were more strongly inhibited when participants retrieved the target means more frequently. Again we expected to find inhibition of the competing means only upon repeated retrieval of the target means. To examine this effect, we tested the contrast of the inhibitory effects, similar to Study 1, in the one-retrieval practice condition against those in the three- and the nine-retrieval practice conditions together (in weights: –2, 1, 1, respectively). In accordance with the findings in Study 1, the results suggest that inhibition only occurred when the target means was repeatedly retrieved for the goal, $F(1, 118) = 4.02$, $p = .047$ (the inhibitory effect did not differ between three- and nine-retrieval practice conditions, $F < 1$). Subsequently, we conducted simple comparison tests to examine the difference between nonretrieved competitors and baseline means for each retrieval-frequency condition

separately. These analyses showed no inhibition effect after one-retrieval practice, $F(1, 117) = 0.20$, *ns*. However, three-times retrieval practice caused inhibition of the competing means, $F(1, 117) = 3.23$, $p = .07$ (albeit only marginally significant), and after nine-times retrieval practice these means were significantly inhibited, $F(1, 117) = 5.03$, $p = .03$. These findings on the recognition task thus replicate those obtained in the goal–means verification task in Study 1.

STUDY 3

So far, the findings of two studies suggest that repeated retrieval of a target means from memory to attain that goal causes inhibition of competing means associated with the same goal. This inhibition effect is assumed to emerge to prevent interference of the competing means that otherwise will hamper the retrieval process. We argued that this inhibition occurs implicitly, that is, inhibited access to competing means in memory upon retrieval of the target means emerges without explicit intent or instructions to do so. However, it may be argued that our experimental setup may encourage participants to use a more deliberate strategy in which they explicitly suppress the competing means from memory to retrieve the target means faster and more accurately.[3] Specifically, participants in both studies were first introduced to two means (e.g., computer, telephone) that both serve a given goal (wanting to chat) and were then asked to repeatedly retrieve a target means (e.g., computer) upon the presentation of a goal. In order to complete this retrieval task successfully, participants would have been well served by strategically inhibiting the competing means (e.g., "I'd better put *telephone* out of mind to do this task as quickly and accurately as I can"). In other words, inhibition of the competitors was likely a strategy in which participants explicitly engaged during the retrieval phase to help them perform the retrieval task quickly and accurately.

To investigate this strategic suppression account, we designed a third experiment in which we instructed participants either to use such a suppression strategy or not, by encouraging them to put the competing means out of mind before retrieving the target means. If the inhibition of competing means is the result of a strategic suppression process, then these means should be recognized slower than baseline means regardless of the instruction conditions. However, there may be another possibility. Specifically, because participants in the strategic condition have the goal to put the competing means out of mind before retrieving the target means, it is likely that the competitors become more accessible and hence more quickly recognized than the baseline means. In other words, under conditions of strategic suppression, the competing means may be facilitated rather than inhibited as a result of intentionally inhibiting them (cf. Wegner, 1994).

Method

Participants and Design

Seventy-three Dutch undergraduates received €5 in return for their participation. Participants were randomly assigned to either one of the following two retrieval strategy conditions: instruction versus no instruction.

Material and Procedure

The materials, instructions, and procedure were similar to those used in Study 2, except for a few changes in the retrieval phase. In this experiment all participants retrieved the means nine times. To test whether the competing means were inhibited as a result of a deliberate strategy, half of the participants were instructed to actively apply the strategy to put the competing means out of mind prior to the retrieval of each target means. They were told that this strategy would help them to retrieve the target means (associated to the same goal) more rapidly and more accurately. The other half of the participants did not receive this instruction.

After the retrieval phase, three different categories of means were created that each included six means: retrieved means, nonretrieved competing means, and (standard) baseline means. Again, participants had to complete the two-letters means string within 5 sec in the retrieval phase. The baseline means were the nonretrieved means of the goals that were not presented during the retrieval phase. Accessibility of the different means was assessed with a means recognition task, and the same rules and instructions applied as in the second study.

Following the recognition task, we checked the instruction manipulation by asking participants to indicate on a 9-point scale from *not at all* (1) to *very strongly* (9) to what extent they tried to put the competing means out of mind to be able to retrieve the target means faster and more accurately.

Results

Retrieval Percentage in Retrieval Phase

We assessed whether participants retrieved the means to the same extent in both instruction conditions. The mean proportions of accurate retrieval showed that participants were very accurate in retrieval of these means; the overall retrieval rate was 97%. No differences in retrieval success were found between the different instruction conditions, $F < 1$, *ns*.

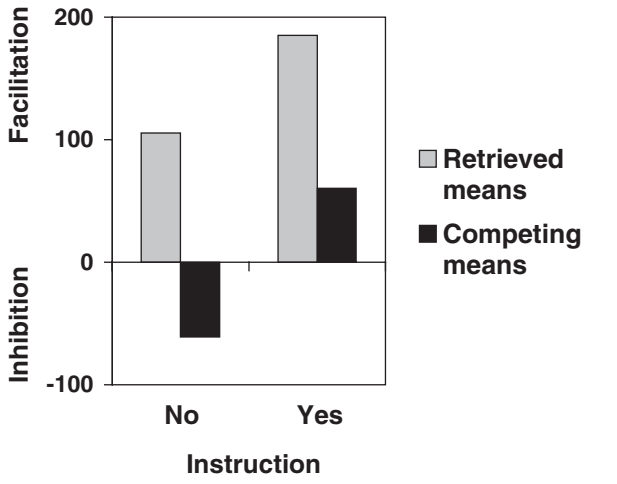

Figure 3 Mean difference scores in reaction time (ms) on the retrieved and competing means with the baseline means per instruction condition. A positive score indicates facilitation, and a negative score indicates inhibition.

Retrieval Instruction Check

An independent-samples *t* test was conducted to examine whether participants in the instruction condition differed from those in the no-instruction condition in their effort not to think about the competing means during the retrieval phase. The test was significant, $t(71) = -2.89$, $p = .005$; participants in the instruction condition more strongly tried to avoid thinking about the competing means ($M = 4.71$, $SD = 2.39$) than did the participants in the no-instruction condition ($M = 3.13$, $SD = 2.22$). The results indicate that participants adhered to our instructions.

Test Phase

Incorrect recognition responses (the number of accurate recognitions was reasonably high: 85%) as well as reaction times higher than three times the standard deviation above the mean (nearly 3% of trials) were excluded from the analyses. The analyses consisted of a 3×2 mixed model ANOVA with type of means (retrieved, baseline, and nonretrieved competing means) as the within-participants factor and instruction (instruction versus no instruction) as the between-participants factor. Figure 3 shows the response latency difference scores between the baseline means and the retrieved means on the one hand and the nonretrieved competing means on the other for the two instruction conditions separately.

Reaction times. We found a main effect of type of means, $F(2, 142) = 54.89$, $p < .001$, as well as an interaction effect between type of means and instruction condition, $F(2, 142) = 7.41$, $p = .001$. Simple comparison tests showed that, overall, participants recognized the retrieved means faster than the baseline means, $F(1, 71) = 95.92$, $p < .001$; access to the retrieved means was facilitated. No overall inhibition effect of the nonretrieved competing means was found, $F(1, 71) = 0.00$, *ns*. However, the differences between the baseline means and the competing means were different between the two instruction conditions, $F(1, 71) = 13.44$, $p < .001$; in the no-instruction condition participants were slower to recognize the competing means in comparison to the baseline means, $F(1, 72) = 5.40$, $p = .023$; the competing means were inhibited. However, in the instruction condition participants were faster to recognize the competing means than the baseline means, $F(1, 72) = 7.32$, $p = .009$. Hence, the competing means were facilitated in the instruction condition.

These data reveal several noteworthy findings. First, the results in the no-instruction condition replicated those of Studies 1 and 2; access to the competing means was inhibited upon repeated retrieval of the target means for the goal. Second, the findings in the instruction condition indicate that the use of a deliberate strategy to put the competitors out of mind prior to the retrieval of the target means facilitated access to these means. Hence, the inhibitory effect found in the previous studies does not seem to result from a deliberate suppression strategy. More likely, they represent an implicit process.

GENERAL DISCUSSION

This research aimed to gain more insight into the cognitive process underlying the initial stage of habit formation in a context where several means are associated and available for the goal. Specifically, we examined the influence of retrieval of the same means to attain specified goals on the accessibility of competing means for that same goal as a function of the retrieval frequency of the target means. The results of three studies show that accessibility of the retrieved means was facilitated and the accessibility of the competing means was inhibited. It is important that the findings of Studies 1 and 2 reveal that the inhibition effect of these competitors was determined by the retrieval frequency of the target means. It was found that the means were not inhibited after a single retrieval from memory but that repetitive retrieval (three or nine times) did lead to inhibition of these means. The evidence for these inhibitory effects after repeated retrieval of target means was provided by two different response latency measures: a goal–means verification task and a means-recognition task. The present findings thus indicate that both facilitative and inhibitory processes underlie the initiation of habit formation.

We argued that inhibition in the initial stage of habit formation to use a specific target means requires practice but that this inhibition occurs implicitly. Specifically, to select the target means it needs to be retrieved from memory in an efficient manner, that is, without interference from competing means. For that reason, an inhibitory link is created in the memory system between the means during succeeding retrieval to inhibit access to the competitors upon goal activation, thereby preventing their mental representation from becoming consciously accessible. Therefore, these competitors are inhibited without strategically suppressing them. In an attempt to test this notion more directly, Study 3 compared the inhibition effects obtained in Studies 1 and 2 with those occurring when participants are encouraged to deliberately suppress competing means. The results indicate that access to the competing means was inhibited when no such deliberate suppression strategy was given (replicating the data of Studies 1 and 2), and explicitly suppressing the competitors prior to the retrieval of the target means did not cause inhibition and even resulted in facilitated access to these means. This dissociative pattern of results provides more convincing evidence for the assumption that the inhibition of competing means during the formation of goal-directed habits can emerge from an implicit process. Accordingly, although one may experience one's decision to use means for goal pursuit as being based on consciously rejecting competing alternatives, our data suggest that these competitors can be inhibited before one becomes aware of them. These findings are consistent with other models of inhibition in which the interference of competing information is solved before this information gains access to consciousness (Anderson & Green, 2001; Dijksterhuis & van Knippenberg, 1998).

Our findings concur with recent work on the role of inhibition in goal-directed behavior (Mayr, 2002) and, moreover, with the findings of Shah and colleagues (2002; see also Shah, 2005) in their work on their goal-shielding model. The present research, however, extends this research in two important ways. First, in the studies the goal–means network was taken into account more directly as opposed to the research of Shah and colleagues (2002). In Shah et al.'s study participants were primed with means (or subgoals) that caused inhibition of competing means, and it was assumed that these effects occurred because the means were connected to the same goal. In the present study, specific goal–means links were created by asking participants to encode the instrumental relation between the means and the goal and, moreover, the accessibility of the different means was assessed after retrieval of the target means for goal attainment. Second, inhibition only emerged after repeated retrieval of a target means from memory. Although Shah et al. speculated about the temporal learning of inhibition in goal systems, they did not investigate this assumption. Our findings, therefore, allow for a firmer conclusion that inhibition of subgoals or means that compete for attention upon the activation of a (higher) goal has to be practiced or learned (see also Chan et al., 2001).

It should be noted that this study investigated the initial stage of the formation of goal-directed habits by exploring the inhibition of competing means as a result of maximally nine repetitions. We are unable to draw conclusions about the role of inhibition in a more advanced stage of the formation process. Although it is difficult to say how many times the retrieval and selection of the target means have to be implemented to categorize the goal-directed behavior as truly habitual (e.g., Aarts et al., 1998; Ronis, Yates, & Kirscht, 1989), it may be worthwhile to speculate on the nature of the inhibitory control of competing means when such habits are in place. First, we did find that competing means are inhibited after nine retrieval performances. This sustained inhibition suggests that competitors remain part of the goal–means network during the formation of habits. However, what will happen when the number of repetitions further increases and habits are established? Are competing means still inhibited? Two possibilities are discussed here.

First, the development of habits may be rather slow, for example, when habits are formed under rather unstable circumstances (Danner, Aarts, & de Vries, 2007; Ouellette & Wood, 1998). For instance, it may be that habits are less easily formed when the interference of competing means is stronger. Strong interference can be the result of two different processes: a high number of competing means associated to the goal or a strong association between the goal and the competing means (Bäuml, 1998; Shivde & Anderson, 2001). Accordingly, a habit to use a target means for attainment of the goal might establish more slowly when numerous competing means are available for goal pursuit (e.g., when wanting to keep one's options open) or when one competing means is strongly associated to the goal (which may be the case when intending to change an existing habit). Inhibition, then, may sustain even after a high number of practice trials. Second, inhibition may dwindle because the competitors lose their functionality as alternatives when the same target means is used over and again in the past. In that case, the association between the goal and competing means decreases in strength and, as a consequence, interference of these means disappears as a result of an associative decrement or extinction effect. An interesting avenue for further research, then, is to investigate these processes in more detail to fully understand and appreciate whether and how inhibitory control shapes and maintains goal-directed habits.

FUTURE DIRECTIONS

This investigation was conducted as a first attempt to analyze the process of habit formation in a context where several means are available for goal pursuit. Our research still has a preliminary status and thus leaves a number of questions open for further examination. First, whereas this research focused on the cognitive mechanism underlying the inhibition of means in a goal–means network, motivational aspects are also an important part of goal-directed behavior (Geen, 1995; Gollwitzer & Moskowitz, 1996). For instance, Shah and colleagues (2002) showed that their goal-shielding effects were stronger when the self-reported commitment (or importance) to pursue the goal was stronger. These findings suggest that motivation may moderate inhibition effects of competing means. It should be noted, though, that commitment and frequency of goal pursuit may be highly correlated; people who are motivated to pursue a goal are more likely to repeat that goal pursuit more often, especially when goal pursuit is successful (Aarts, Paulussen, & Schaalma, 1997; Weiner, 1985). Thus, whereas the current data did not show effects of motivation on inhibition, they may have demonstrated a potential mediator of motivation on inhibition during habit formation. However, because this line of thought is not directly tested in these studies, it awaits further empirical scrutiny.

Another issue pertains to the notion that interference and, hence, inhibition only occurs when information competes for attention or behavior. Because people's behavior system usually allows them to do one thing at a time, inhibition plays an important role in sequential aspects of goal-directed behavior, even though the performance of subactions (e.g., first turning left, then turning right) facilitate goal achievement (e.g., Mayr, 2002). However, in the context of goal–means network, it is suggested that inhibition only emerges when the means are competitive. This notion is supported by recent work. Shah and colleagues (2002) showed that the degree of competition between subgoals or means was positively related to the goal-shielding effect. That is, "inhibition of alternative goals was found to be more pronounced when they serve the same overarching purpose as the focal goal, but lessened when the alternative goals facilitate focal goal attainment" (Shah et al., 2002, p. 1261).

In this research the means were encoded as competitors for the given goals and, in line with Shah and colleagues' (2002) findings, these means were inhibited when participants repeatedly retrieved the same means for attainment of the same goal. These findings, though, leave open the possibility that it was not so much the competitive nature of the means that caused the inhibition effect but simply the fact that these means were associated to the goal (albeit competitive or complementary means) and therefore competed for attention during the retrieval. Although we believe that the formation of goal-directed habits may benefit from the inhibition of any interfering information at the moment of retrieving habitual means, future research could address how the nature of the means may, cognitively and behaviorally, facilitate or hinder the formation of habits.

CONCLUDING REMARKS

We observed that competing means are inhibited as a result of repeated retrieval of target means for goal attainment. Our studies suggest that inhibitory control may play an important role in the early stage of the formation of goal-directed habits. Inhibition is a functional mechanism to ease goal attainment: People are able to make fast and reliable decisions about how to attain their goal by getting rid of the interference of accessible means that otherwise compete for attention. So the more often one chooses fruit salad when ordering dessert, the less likely ice cream comes to mind.

NOTES

1. Analysis of variance (ANOVA) on the "no" responses showed that participants less frequently responded with "no" to retrieved means than to baseline and competing means. However, because controlling for these differences in the ANOVA with the reaction times as dependent variable did not change the reported pattern of results, they are not further reported in the analyses.

2. ANOVA on the recognition accuracy scores showed that participants' accuracy scores in Study 2 and Study 3 were higher for retrieved means than for baseline and competing means. However, because controlling for these differences in the ANOVA with the reaction times as dependent variable did not change the reported pattern of results, they are not further reported in the analyses.

3. We thank one of the reviewers for suggesting this alternative explanation.

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