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Intention formation induces episodic inhibition of distracting stimuli

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Abstract

In two experiments we show that (a) distracting stimuli are inhibited after intention formation, (b) this inhibition is episodic rather than semantic in nature, and (c) inhibition of distracting stimuli is terminated once intentions are completed. In both experiments participants were asked to form an intention to press the space bar in response to six cues (i.e. intention cues). After intention formation we measured accessibility of intention cues, of words that are semantically related to the intention cues (i.e. related cues) and of semantically unrelated words (i.e. control cues). In Experiment 1, we obtained slower responses towards related cues compared with both intention cues and control cues in a recognition task, but not in a lexical decision task. In Experiment 2, we showed that inhibition of related cues is terminated after intention completion. Together these results are consistent with theorizing that inhibition of distracting (i.e. related) stimuli is functional for completing previously formed intentions, and give insight in the nature of inhibitory processes during goal pursuit.

PsycINFO classification: 2340

Keywords: Memory; Inhibition; Intention; Distraction

1. Introduction

Keeping in mind what to do is indispensable for successful goal pursuit. However, such maintenance of intentional information in memory may not be as straightforward as it seems. For instance, imagine that you just taught a class for the first time, and learned the names of all 10 participants. After class, five participants come up to you asking for some additional information. You promise them to e-mail this information when you get to your office. To ensure that this intention will be completed successfully, it is essential to keep the specific names of these five participants in memory. This seems by no means easy as you just learned 10 new names. Still, many people seem able to regulate their behavior in a way that ensures intention completion even in the presence of many distracting stimuli. The nature of the process that targets the status of distracting stimuli during goal pursuit is the focus of the current experiments.

The idea that intentions are protected from distraction can be found in several volitional approaches to goal striving (e.g. Gollwitzer, 1990; Heckhausen & Gollwitzer, 1987; Kuhl, 1987, 2000; Mischel, Cantor, & Feldman, 1996). According to a model of action control by Kuhl (1987), protection from distraction originates from the nature of intentions. Kuhl describes an intention as "...an activated plan to which an actor committed herself or himself..." (p. 282). This definition entails two distinct properties of intentions that are represented in separate memory systems. First of all, intentions have a structural component that consists of the content of the intention, which includes both the plan (i.e. what to do) and behavioral programs for intention execution. In addition, intentions require the activation of a motivational maintenance system (MMS). This

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system is free of content, but, when activated, directs activation to any structure that is currently most accessible in content-specific memory systems. MMS ensures that an activated plan remains active over time and is protected against competing plans (Kuhl, 1987; see also Anderson's (1983) adaptive control of thought (ACT*) model for enhanced accessibility of intention related information).

However, although the MMS can account for shielding a specific intention from irrelevant information (i.e. by keeping the intention activated; Goschke & Kuhl, 1993) it does not address what happens when stimuli are present that are strongly related to the intentional content. As the MMS does not discriminate on the basis of content, but sends activation to any content that is most accessible in other memory systems, related stimuli might become activated erroneously, resulting in errors in intention execution. It seems that in situations in which such distracting (i.e. related) stimuli are present, additional regulatory processes are required to shield intentions from oblivion.

Because the MMS sends activation on the basis of content accessibility and not content itself, the presumed additional regulation is most likely controlled by content-specific memory systems. These systems can determine whether certain stimuli might interfere with the content of an intention, and as a result fend off these distractions. However, the question remains *how* content-specific mechanisms resolve which information should be fended off.

Although selective inhibition of distracting stimuli in the domain of intentions has not yet been examined often, inhibition of distracting information compared with neutral information has already been studied repeatedly in the domain of long-term memory, specifically retrieval-induced forgetting (RIF; Anderson, Bjork, & Bjork, 1994). In the RIF paradigm participants memorize category-exemplar pairs from two or more semantic categories. After this study phase participants perform retrieval practice on half of the exemplars of some of the studied categories by means of category-word stem completion. After retrieval practice, recall or accessibility of all studied exemplars is measured. Research in this domain has shown that recall (e.g. Anderson et al., 1994; Anderson & Spellman, 1995) and accessibility (Veling & van Knippenberg, 2004) of unpracticed exemplars from the practiced categories is inferior to recall and accessibility of unpracticed exemplars from the unpracticed categories. The explanation for this effect is that retrieving a subset of exemplars from a semantic category during retrieval practice inhibits access to distracting exemplars from the same category, to facilitate the selection of the to be retrieved exemplars.

Anderson (2003) and Veling and van Knippenberg (2006) have argued that inhibitory mechanisms that aid selection of information in long-term memory might also operate to shield intentions from distracting stimuli. Both selection of information in long-term memory and maintaining intentions active in memory benefit from inhibition of distracting stimuli in order to complete their respective tasks (see also Anderson & Spellman, 1995; Dijksterhuis & van Knippenberg, 1998).

To test the idea that distracting stimuli are indeed inhibited after intention formation, Veling and van Knippenberg (2006) conducted two experiments in which they asked participants to do a lexical decision task and in addition press the space bar after lexical decisions towards a selection of specific words (i.e. intention words). During this lexical decision task, they also presented words that were previously studied and semantically related to the intention words (i.e. related words) and previously studied semantically unrelated words (i.e. control words). The idea is that, as in RIF research, the related stimuli need to be inhibited to prevent interference with target stimuli, in this case prevent interference with the intention words. Results showed slower lexical decisions towards related words compared with both intention words and control words. This latter comparison is important, because it indicates that related words were indeed inhibited. Based on these results, Veling & van Knippenberg concluded that distracting stimuli are inhibited after intention formation.

However, a problem with the paradigm just described is that participants performed a lexical decision task and simultaneously scanned for intention words. Consequently, every letter string in the lexical decision task was probably evaluated as a potential word (i.e. is it part of the existing lexicon), and as a potential intention cue (i.e. is it part of the set of intention words). Therefore, slower lexical decisions towards distracting words could either indicate that these words were slower recognized as existing words, or that they were slower rejected as being part of the intention cues, or both. Thus, it is not clear whether the increased reaction times towards the distracting stimuli (Veling & van Knippenberg, 2006) concern inhibition of (semantic) access towards distracting words, i.e. semantic inhibition, or inhibition of distracting words as potential intention cues, i.e. episodic inhibition (for episodic priming effects in a lexical decision task see Durgunoglu & Neely, 1987).

To solve this problem it is useful to theorize about *where* inhibition of distracting stimuli in maintaining an intention in mind would take place. A particularly useful model for the present purposes is that of O'Reilly and Rudy that distinguishes between a cortical system and a hippocampal system. The cortical system learns slowly and contains information that is extracted from many experiences. As a result, information in this system contains generic features of stimuli or situations. The hippocampal system on the other hand, learns fast and contains information concerning specific events. Importantly, the hippocampal system has distinct features that are important for intention formation. Firstly, whereas the cortical system needs many experiences to extract generalities of situations and stimuli, the hippocampal system can store an integrated representation of a single event. Furthermore, the hippocampal system uses a principle, called *pattern separation*, to ensure that each event is stored without overlap with previous events. This principle prevents interference between related events. Finally, an important principle is *pattern completion*, which enables us to recover a full memory representation (your car is parked between two trees in the middle of the parking lot) based on partial input (someone asking you, "where is your car"). Together, these features ensure that we can remember where we parked our car today (O'Reilly and Rudy, 2001).

Although a dual memory systems approach concerning long-term memory is usually applied to retrospective memory (e.g. the current location of your car) we think it is a highly useful distinction in the area of remembering intentions also. When forming an intention (e.g. whom to e-mail what) remembering the intention depends on successfully storing a (single) specific event that should not overlap with previous experiences. Such a storage is exactly what the hippocampal system does. Therefore, it seems plausible that the representation of intentions is stored in the hippocampal system rather than the cortical system. This idea particularly holds for new intentions that have not been formed frequently in the past. Note that as we do not measure neurological activation directly, we will hereafter refer to the hippocampal system as episodic memory and the cortical system as semantic memory.

So, in order to successfully execute an intention, it is important to maintain a clear representation of the intention in episodic memory. Although this memory system already uses pattern separation to make a distinct representation of this intention during intention formation, this may not always be sufficient when there is a high degree of resemblance between intentional and other episodic content. Put concretely, when we first encounter 10 students during class and then form an intention to e-mail five of them after class, we store two episodic representations of the five target students: One in the representation of the intention and one in the representation of the whole class. When activating the five target names of the intention representation, there is the danger of completing the pattern of the whole class memory representation resulting in interference. A solution to this problem would be that stimuli that are strongly related to an intention in episodic memory are inhibited in episodic memory. By inhibiting the related stimuli, pattern completion becomes more difficult and interference pertaining to the intention is less likely. Thus, in the present research we hypothesize that forming an intention leads to inhibition of related stimuli in episodic memory.

1.1. Overview of experiments

In both experiments, participants were first presented with stimuli from six semantic categories. We instructed participants to press the space bar whenever a fruit (e.g. mango, grape, etc.), animal (e.g. lion, giraffe, etc.), or profession (teacher, notary, etc.) was presented. This phase was included to ensure that all stimuli were activated in episodic memory. After this first task, we asked participants to form an intention to press the space bar to specific stimuli in the final task of the experiment (e.g. press space bar when you see the word *mango* or *lion*). Note that after this point two representations of the intention stimuli are stored in episodic memory: One as part of the first task and one as a representation of the intention. Before (Experiments 1 and 2) or after (Experiment 2) executing this intention, we measured accessibility of intention words (e.g. *mango*, *lion*), words semantically related to this intention (e.g. *grape*, *giraffe*), and control words (e.g. *teacher*, *notary*). We expected inhibition of words related to the intention (e.g. *grape*, *giraffe*), when inhibition was measured before intention execution in episodic memory. In Experiment 1, we tested this hypothesis by measuring accessibility by means of either a recognition task (tapping episodic memory) or a lexical decision task (tapping semantic memory). We hypothesized slower responses towards stimuli that are related to intentional stimuli (e.g. *grape*, *giraffe*) compared with stimuli that are unrelated to intention relevant stimuli (e.g. *teacher*, *notary*) in the recognition task only. In Experiment 2, we measured accessibility with a recognition task only, but this time either before or after intention execution. We expected that inhibition of distracting stimuli would vanish after intention execution.

2. Experiment 1

2.1. Method

2.1.1. Participants and design

Sixty undergraduate students participated in Experiment 1 in exchange for €2 (approximately $2.40). The design was a 3(stimulus type: intention, related, control) by 2(task type: recognition vs. lexical decision) mixed design with repeated measures on the first factor.

2.1.2. Materials and procedure

Participants were tested individually and read self-paced through instructions on a computer screen. See Fig. 1 for an outline of the experimental procedure. We first instructed participants to press the space bar towards any stimulus from three semantic categories (fruits, animals and professions) and not towards stimuli from three other categories (clothing, sports and musical instruments). We presented six stimuli of each category in random order. These stimuli were selected from a study in which Dutch category-exemplar pairs were generated (Storms, 2001). Participants received feedback whenever they responded erroneously. This phase was included to activate all stimuli in memory.

Next, participants read that they would receive the task they just finished once more in the third phase of the experiment. However, instead of pressing the space bar in response to any fruit, animal and profession, participants were asked to form an intention to press the space bar only in response to six specific stimuli from two categories (e.g. strawberry, mango, plum, elephant, rabbit, lion) in the third part of the experiment. These six exemplars were then

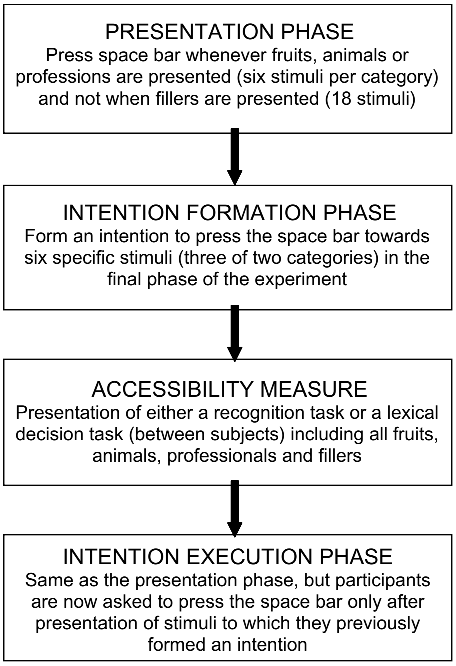

Fig. 1. Outline of experimental procedure of Experiment 1.

simultaneously presented for 30 s. Besides these *intention stimuli* this manipulation generated two kinds of intention-irrelevant stimuli. First of all, the manipulation created stimuli that are semantically related to the intention stimuli (e.g. melon, grape, lemon, giraffe, camel, bull). Because these stimuli are semantically related to the intention stimuli we will call these stimuli *related stimuli*. In addition, there are stimuli that are semantically unrelated to the intention stimuli (e.g. teacher, hairdresser, notary, lawyer, butcher, pilot) as these stimuli were presented as part of a different semantic category. We will refer to these stimuli as *control stimuli*. To ensure that every exemplar would function as an intention stimulus, related stimulus, or control stimulus, six sets were constructed in which the function of exemplars varied between participants.

Before executing this intention we measured accessibility of all stimuli presented in the first phase by means of either a recognition task or a lexical decision task. In the recognition task condition, participants read that words presented on the screen would be either new or taken from the first phase of the experiment. In addition, these participants read that some new words were new exemplars from the same categories they had seen in the first phase. Thus, their recognition decision could not be based on category membership alone. In the lexical decision condition participants read that the task was to decide whether letter-strings presented on the computer screen were Dutch words. To ensure fast reaction times we included a response window of 3 s in both tasks. When a reaction time exceeded this window participants received an instruction to respond faster.

In both the recognition task and the lexical decision task an asterisk preceded presentation of the stimuli. After a random interval of between 1 and 1.5 s the target replaced the asterisk and participants were asked to respond as quickly and accurately as possible. The intertrial interval was 1.5 s. Two orders of stimulus presentation (new words and old words in the recognition task or words and non-words in the lexical decision task) were constructed to prevent the same response from occurring more than three times in a row. Within these two orders the stimuli were randomly selected. One of these orders was randomly selected between participants.

Apart from 36 old words from the first phase of the experiment, the recognition task encompassed two types of filler words. To ensure that decisions in the recognition task could not be based on category membership alone, we included three new exemplars of each semantic category of old words (fruits, animals, professions, clothing, sports, musical instruments; a total of 18 exemplars). In addition, we presented 18 words that did not belong to any of the categories. Thus, the recognition task included 72 trials and the probability of encountering a new word was 50%.

In the lexical decision task we presented participants with the 18 experimental exemplars, nine new words from the experimental categories (fruits, animals, clothing), 27 new words that were not part of any of the categories, and we included 54 pronounceable letter strings that are not part of the Dutch vocabulary as non-words. These new words and non-words were matched for word length to the experimental exemplars. Consequently, the lexical decision task consisted of 108 trials and the probability of encountering an existing word was 50%. Before starting the lexical decision task participants received six practice trials (including three words and three non-words).

The final intention execution phase was identical to the first phase experiment except for two changes. First, participants were instructed to press the space bar in response to the exemplars for which they previously formed an intention only. In addition, they did not receive feedback whenever they made an erroneous response. Afterwards they were thanked and paid for their participation.

2.2. Results

One participant was excluded from the following analyses because this participant made an erroneous recognition decision in more than 33% of the trials (which was more than three standard deviations above the mean error rate in the recognition task condition). Next, we excluded trials in which a response was incorrect (15.5% of responses in the recognition task condition and 3.5% of the responses in the lexical decision task condition) and trials in which response latencies exceeded the window limit (0.5% and 0.3% for the recognition task and lexical decision task, respectively). To reduce the impact of incidental slow latencies, analyses were performed on log-transformed data. However, reliability of the analyses is not affected by this transformation in any meaningful way. For the sake of clarity, we report non-transformed means.

Table 1
Mean reaction times in milliseconds and standard deviations (in brackets) as a function of type of task and type of stimuli in Experiment 1

	Type of stimuli					
	Intention	Related	Control	New words	Old (filler) words	Non-words
Recognition task	759 (142)	861 (183)	784 (138)	843 (126)	888 (166)	–
Lexical decision task	602 (148)	581 (114)	601 (157)	614 (116)	–	666 (134)

Note: Old (filler) words are words that were filler words in the first phase of the experiment. New words are words that were not presented in the first phase of the experiment.

2.2.1. Analyses of reaction time data

Table 1 displays the mean reaction times concerning the different kinds of stimuli in Experiment 1. To test whether forming an intention causes inhibition of related stimuli in the recognition task only, we performed a stimulus type (intention, related, control) by task type (recognition or lexical decision) mixed analysis of variance (ANOVA) with repeated measures on the first factor. First of all, a main effect of task type emerged. Participants in the recognition task condition reacted slower ($M = 801$ ms, $SD = 136$) than participants in the lexical decision task condition ($M = 594$ ms, $SD = 129$), $F(1,57) = 41.22$, $MSE = 0.018$, $p < 0.01$, partial $\eta^2 = 0.42$. More important, however, the predicted interaction between stimulus type and task type was reliable, $F(2,114) = 8.52$, $MSE = 0.018$, $p < 0.01$, partial $\eta^2 = 0.13$.

In the recognition task condition (see Table 1) simple effect tests revealed increased reaction times to related stimuli compared with both intention stimuli and control stimuli, respective comparisons $F(1,28) = 17.07$, $MSE = 0.002$, $p < 0.01$, $\eta^2 = 0.38$, and $F(1,28) = 9.35$, $MSE = 0.002$, $p < 0.01$ $\eta^2 = 0.25$. The latter test, i.e. the contrast between related stimuli and control stimuli is crucial in demonstrating the occurrence of inhibition. Consistent with our prediction results show that only strong associates to the intention stimuli receive inhibition. Finally, there was no reliable difference between the intention and control stimuli, $F(1,28) = 2.37$, $MSE = 0.002$, $p = 0.14$, $\eta^2 = 0.08$.

In the lexical decision task condition (see Table 1), there were no reliable differences between related stimuli and either intention stimuli or control stimuli, respective comparisons $F(1,29) = 1.54$, $MSE = 0.001$, $p = 0.22$, $\eta^2 = 0.05$ and $F < 1$. The comparison between intention and control stimuli was also not reliable, $F < 1$. So, in contrast to episodic accessibility, semantic accessibility of the stimuli was not affected by our intention formation manipulation.

2.2.2. Analyses of error data

The pattern of the error data is similar to the reaction time data, but less reliable (see Table 2). In the recognition task condition, more errors were made concerning related stimuli compared with intention stimuli, $F(1, 28) = 8.74$, $MSE = 0.79$, $p < 0.01$, $\eta^2 = 0.24$. The differences between related and control, and intention and control are not reliable (respective comparisons $F(1, 28) = 1.03$, $MSE = 1.36$, $p = 0.32$, $\eta^2 = 0.04$ and $F(1, 28) = 2.30$, $MSE = 0.91$, $p = 0.14$, $\eta^2 = 0.08$). In the lexical decision task condition there are no reliable differences in mean numbers of errors between intention, related, and control stimuli (all Fs < 1). Overall, this pattern provides additional support for the idea that related stimuli are inhibited in episodic memory only.

Table 2
Mean number of errors and standard deviations (in brackets) as a function of type of task and type of stimuli in Experiment 1

	Type of stimuli		
	Intention	Related	Control
Recognition task	0.52 (0.78)	1.21 (1.11)	0.90 (1.01)
Lexical decision task	0.10 (0.40)	0.17 (0.53)	0.20 (0.40)

2.2.3. Analyses of intention execution phase

Firstly, we checked whether there was a difference in intention execution speed between the recognition task condition ($M = 653$ m s, $SD = 104$) and the lexical decision task condition ($M = 671$ ms, $SD = 143$). However, no reliable difference was found ($F < 1$). Next, we analyzed mean numbers of errors, but no difference in mean number of errors between the recognition task condition ($M = 1.90$, $SD = 2.08$) and the lexical decision task condition ($M = 2.07$, $SD = 2.39$) emerged ($F < 1$). Finally, we performed a number of analyses to check whether inhibition of related stimuli in the recognition task condition was related to intention execution, but we obtained no reliable relations.

2.3. Discussion

The results of Experiment 1 show that stimuli that are related to an intention, through semantic interrelations, are recognized more slowly as being presented previously, than either stimuli unrelated to the intention or intention cues. There were no differences between these kinds of stimuli when participants were asked to recognize these stimuli as being words. This result is consistent with our hypothesis, because these data suggest that the related stimuli are inhibited in episodic rather than semantic memory. As explained in Section 1, this makes sense because intention stimuli are episodic representations that need to be protected from related episodic representations. Furthermore, and consistent with an inhibitory explanation, we found that, compared with intention stimuli, related stimuli were more often judged as being new in the recognition task, with control stimuli falling in between. So, it appears that episodic memory protects the content of intentions by inhibiting content that, through intrusion, might impede proper intention execution.

We did not find any relations between the accessibility of stimuli in episodic memory and intention execution. We do not want to elaborate too much on this issue as there may be a variety of reasons to explain this non-finding. For instance, it could simply be that the go/no-go intention execution task that we employed is not sensitive enough to reveal any relations between inhibition and intention execution. With regard to this issue we would like to stress that the focus of the present research is on the representation of intention relevant information in memory, i.e. memory for *content* of intentions (Goschke & Kuhl, 1993), and not on successful intention execution, i.e. memory for *intent,* as in the domains of event-based (Marsh, Hicks, & Watson, 2002) and time-based prospective memory (Einstein, McDaniel, Smith, & Shaw, 1998).

In addition, we did not find any performance differences in intention execution between participants that received the recognition task compared with participants that received the lexical decision task. This is noteworthy, because it suggests that determining whether stimuli are part of a previously presented set, that contained both related and intention stimuli, did not lead to more confusion concerning the identity of the intention stimuli than a task in which participants were simply asked whether letter strings are words. However, as in the previous paragraph, we think that this non-finding should be treated rather cautiously.

As is apparent from Table 1, in the recognition task we did not obtain a facilitation effect of intention stimuli compared with control stimuli. It is important to point out that we do think that intentions have a special status in memory in terms of activation. This aspect of intentions is well documented both in theorizing on motivation, and research concerning the representation of intentional information in memory (e.g. Anderson, 1983; Goschke & Kuhl, 1993; Kuhl, 1987, 2000; Lau, Rogers, Haggard, & Passingham, 2004; Marsh, Hicks, & Bink, 1998). However, the present paradigm was designed to show inhibition of related stimuli and not to show enhanced activation of intention related content. In order to achieve this goal, we first presented participants with all stimuli and asked them to react to these stimuli based on their category membership. This procedure ensured that all stimuli became highly activated. As a result, protecting an intention could not be achieved by enhancing activation of intention stimuli (i.e. because all stimuli are already activated), but protection was realized by inhibiting related stimuli instead.

On the other hand, Goschke and Kuhl (1993) found enhanced activation of intentional information compared with other to be remembered information, even though all information was memorized in the first phase of the experiment. However, Goschke and Kuhl compared only two kinds of information, i.e. intention stimuli versus to be remembered stimuli. It is unclear whether to be remembered stimuli in their paradigm should be viewed as distracting stimuli (because participants were asked to memorize these stimuli) or as control stimuli. Consistent with this interpretation, they concluded that their results (faster recognition of intention stimuli) could be interpreted as a result of facilitation of intention stimuli, or inhibition of other information, or both.

Finally, we like to emphasize that the inhibition of related stimuli observed in Experiment 1 cannot easily be explained as a side effect of the mere presentation of intention cues in the intention formation phase, as is the case in part-list cuing inhibition (e.g. Basden & Basden, 1995). Specifically, part-list cuing inhibition refers to the phenomenon that, after memorizing a list, presenting part of the list during a recall task impairs memory for the whole list. Part-list cuing inhibition is likely caused by a disruption of retrieval processes when part of the list is available during retrieval of the whole list. The key issue is that part-list cuing is not obtained when the presentation of part of the list (in our case presentation of intention cues) and measurement of memory for the whole list (in our case in the recognition task) are separated (see Basden & Basden, 1995). Furthermore, research on retrieval-induced forgetting has also repeatedly shown that when part of a memorized list and the whole memorized list are presented in separated phases of an experiment, mere presentation of part of the list is not sufficient to obtain any inhibition when memory for the whole list is tested (Anderson, Bjork, & Bjork, 2000; Bäuml, 2002). Nevertheless, in Experiment 2 we aimed to obtain more direct evidence that the inhibition of related stimuli is indeed a specific result of intention shielding.

3. Experiment 2

In Experiment 2 we intend to replicate the inhibition of related stimuli in a recognition task that we observed in Experiment 1. In addition, we explore whether this inhibition was in fact a result of intention shielding and not, as described above, a side effect of the presentation of (intention) exemplars in the intention formation phase. To do so, we examine the status of related stimuli after completion of the intention.

According to the model of action phases by Kuhl (1987) outlined in Section 1, the MMS stops sending activation to content of an intention once an intention is completed or abandoned. Consistent with this idea, research has shown that, upon intention completion, intentional content is no longer in a heightened state of activation in memory (Marsh et al., 1998; see also Förster, Liberman, & Higgins, 2005). Additionally, we think that once the MMS ceases to send activation to intentional content, information that is related to this content will no longer be considered as distracting (i.e. because there is nothing to interfere with). Without being a source of potential interference, previously related stimuli will require no inhibition and, as a result, accessibility of related stimuli concerning such a completed intention will be released and returns to baseline level.

To test this theory, participants in Experiment 2 received the recognition task either before or after intention completion. We hypothesized inhibition of related stimuli compared with control stimuli, before, but not after intention completion.

3.1. Method

3.1.1. Participants and design

Eighty-one undergraduate students participated in Experiment 2 in exchange for €2 (approximately $2.40). The design was a 3(stimulus type: intention, related, control) by 2(intention status: completed vs. uncompleted) mixed design with repeated measures on the first factor.

3.1.2. Materials

The stimuli used in Experiment 2 were identical to those used in Experiment 1.

3.1.3. Procedure

The procedure in both intention status conditions of Experiment 2 (completed vs. uncompleted) was identical to the procedure of the recognition task condition of Experiment 1 except for one important change in each condition. See Fig. 2 for an outline of the experimental procedure per condition. Participants in the completed intention condition received the intention execution task directly following intention formation and before the recognition task. This way the recognition task would measure accessibility of intention, related and control stimuli after intention completion. After the recognition task participants in the completed intention condition were thanked and paid for their participation.

After intention formation participants in the uncompleted intention condition received the first task of the experiment for the second time. So, they were again asked to press the space bar in response to all fruits, animals and professions. This second presentation ensured that exposure to all stimuli in the recognition task in this condition is comparable with exposure of the stimuli in the recognition task in the completed intention condition (that is, by the time participants engage in the recognition task, in both conditions all intention stimuli have been encountered three times (including the intention formation) and related and control stimuli twice). Finally, following the recognition task participants in the uncompleted intention condition were presented with the intention execution task that required them to press the space bar in response to specific exemplars for which they previously formed an intention. After that participants in this condition were thanked and paid for their participation.

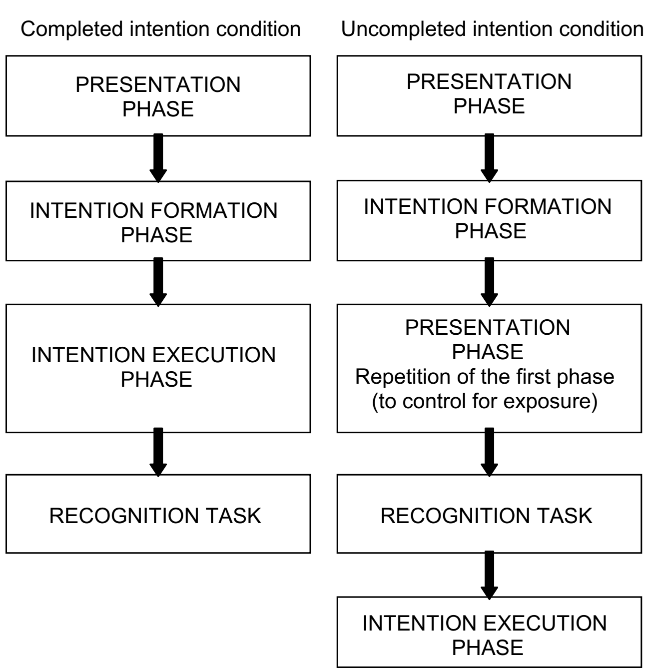

Fig. 2. Outline of experimental procedures of the completed intention condition and the uncompleted intention condition of Experiment 2.

3.2. Results

Three participants were excluded from the following analyses. One participant responded erroneously in more than 75% of the trials. After excluding this participant, two additional participants were excluded because they responded erroneously in more than 33% of the trials (which was, just as in Experiment 1, more than three standard deviations above the mean error rate). Next, we excluded trials in which a response was incorrect (9.0% of responses in the completed intention condition and 11.1% of responses in the uncompleted intention condition) and trials in which response latencies exceeded the window limit (0.3% and 0.2% for the completed and uncompleted intention conditions, respectively). Analyses were again performed on log-transformed data, but we report non-transformed means.

3.2.1. Analyses of reaction time data

To test whether the status of an intention (completed vs. uncompleted) would differently affect inhibition of related stimuli we performed a stimulus type (intention, related, control) by intention status (completed vs. uncompleted) mixed analysis of variance (ANOVA) with repeated measures on the first factor. The means are shown in Table 3. First of all a main effect of stimulus type appeared. Overall participants were the fastest to indicate that an intention stimulus was presented before ($M = 710$, $SD = 140$) and slowest to indicate that a related stimulus was presented before ($M = 754$, $SD = 167$) with recognition latencies towards control stimuli in between ($M = 737$, $SD = 169$), $F(2, 152) = 5.53$, $MSE = 0.002$, $p < 0.01$, partial $\eta^2 = 0.07$. However, this effect was qualified by a reliable interaction with intention status, $F(2, 152) = 3.93$, $MSE = 0.002$, $p < 0.05$ partial $\eta^2 = 0.05$.

Table 3
Mean reaction times in milliseconds and standard deviations (in brackets) as a function of intention status and type of stimuli in Experiment 2

	Type of stimuli				
	Intention	Related	Control	Old (filler) words	New words
Uncompleted	707 (119)	756 (177)	705 (119)	802 (112)	785 (114)
Completed	712 (118)	752 (160)	768 (203)	805 (149)	774 (161)

Note: Old (filler) words are words that were filler words in the first phase of the experiment. New words are words that were not presented in the first phase of the experiment.

To test whether uncompleted intentions caused inhibition of related stimuli (see Table 3), we performed simple effect tests between stimulus types within the uncompleted intention condition. These tests revealed increased reaction times to related stimuli compared with both intention stimuli and control stimuli, respective comparisons $F(1,\ 37) = 4.73$, $\mathrm{MSE} = 0.001$, $p < 0.05$, $\eta^2 = 0.11$, and $F(1,\ 37) = 4.17$, $\mathrm{MSE} = 0.002$, $p < 0.05$, $\eta^2 = 0.10$. This latter reliable contrast between control and related stimuli shows that intention formation causes inhibition of related stimuli. There was no reliable difference between the intention and control stimuli, $F < 1$. This pattern of results is a replication of the recognition task condition of Experiment 1, and consistent with our hypothesis in showing that stimuli that are related to an intention are indeed inhibited.

Next, we examined simple effects between stimulus types in the intention completion condition (see Table 3). As predicted, there was no reliable difference between the related and control stimuli, $F(1, 39) = 1.1$, $\mathrm{MSE} = 0.002$, $p = 0.30$, $\eta^2 = 0.03$. This pattern of results is consistent with our hypothesis that inhibition of related stimuli is faded out when an intention is completed.

Furthermore, simple effect tests revealed decreased reaction times to intention stimuli compared with both related stimuli and control stimuli, respective comparisons $F(1,\ 39) = 8.28$, $\mathrm{MSE} = 0.001$, $p < .01$, $\eta^2 = 0.18$ and $F(1,\ 39) = 14.86$, $\mathrm{MSE} = 0.001$, $p < .01$, $\eta^2 = 0.28$. We think that this facilitation is a result of intention execution, and reflects strengthening of the link between action and responding to intention stimuli.

Because we define inhibition as the difference between control and related stimuli we focused our analyses on comparisons of stimuli within conditions, as these stimuli received similar treatment within each condition. However, when comparing the mean reaction times in Table 3 between each condition, it may give the impression that the control stimuli were inhibited in the completed condition rather than that the related stimuli became disinhibited. Importantly, though, as there is no reliable difference between the control stimuli of the completed condition and the control stimuli of the uncompleted condition, $F(1,\ 77) = 2.90$, $\mathrm{MSE} = 0.007$, $p = .09$, $\eta^2 = 0.04$, this interpretation is not supported. Thus, the most straightforward interpretation of the pattern of results is that related stimuli are indeed inhibited until an intention is completed.

3.2.2. Analyses of error data

As in Experiment 1, the pattern of the error data in Experiment 2 is similar to the reaction time data, but less reliable (see Table 4). In the uncompleted condition more errors were made concerning related stimuli compared with intention stimuli, $F(1,\ 37) = 7.07$, $\mathrm{MSE} = 0.48$, $p < 0.05$, $\eta^2 = 0.16$. The differences between related and control and intention and control are not reliable (respective comparisons $F(1,\ 37) = 1.61$, $\mathrm{MSE} = 0.40$, $p = 0.21$, $\eta^2 = 0.04$ and $F(1,\ 37) = 2.40$, $\mathrm{MSE} = 0.44$, $p = 0.13$, $\eta^2 = 0.06$). In the completed condition fewer errors were made concerning intention stimuli compared to both related and control stimuli (respective comparisons $F(1,\ 39) = 10.01$, $\mathrm{MSE} = 0.25$, $p < 0.01$, $\eta^2 = 0.20$ and $F(1,\ 39) = 10.76$, $\mathrm{MSE} = 0.51$, $p < 0.01$, $\eta^2 = 0.21$). There is no reliable difference in mean number of errors between related and control stimuli ($F < 1$).

3.2.3. Analyses of intention execution phase

First of all, we checked whether there was a difference in intention execution speed between the uncompleted condition ($M = 646$ ms, $\mathrm{SD} = 117$) and the completed condition ($M = 602$ ms, $\mathrm{SD} = 102$). However, no reliable difference emerged, $F(1,\ 76) = 3.16$, $\mathrm{MSE} = 0.12$, $p = 0.08$, $\eta^2 = 0.04$. Next, we analyzed mean numbers of errors (excluding 1 participant in the uncompleted condition who's error rate was beyond 5 SDs from the mean error rate), and we found a reliable difference between the uncompleted condition ($M = 1.76$, $\mathrm{SD} = 1.50$) and the completed condition ($M = 0.78$, $\mathrm{SD} = 1.89$), $F(1,\ 75) = 6.32$, $\mathrm{MSE} = 2.93$, $p < 0.05$, $\eta^2 = 0.08$. So, during the intention execution task fewer errors were made in the completed condition than in the uncompleted condition. We think this effect is the result of the fact that in the completed condition, intention execution followed intention formation immediately. Finally, we performed several analyses to check whether inhibition of related stimuli in the uncompleted condition was related to intention execution, but no reliable relations were found.

Table 4
Mean number of errors and standard deviations (in brackets) as a function of intention status and type of stimuli in Experiment 2

	Type of stimuli		
	Intention	Related	Control
Uncompleted	0.21 (0.58)	0.63 (0.79)	0.45 (0.72)
Completed	0.08 (0.27)	0.43 (0.71)	0.60 (1.06)

3.2.4. Additional analyses

Because we used new exemplars of the experimental categories (fruits, animals and professions) as filler words we could compare reaction latencies to new exemplars from the category of intention stimuli (i.e. new related stimuli) with new exemplars from the category of control stimuli (i.e. new control stimuli), to test whether inhibition of related stimuli is indeed constraint to (old) related stimuli that are represented in episodic memory. To enhance power, we tested this difference in a collapsed data set of the recognition task condition of Experiment 1 and the uncompleted intention condition of Experiment 2. We found no reliable difference between new related ($M = 873$ ms, $SD = 187$) and new control stimuli ($M = 861$ ms, $SD = 193$). This result is consistent with our theorizing in Section 1 as it suggests that stimuli that are merely semantically, and thus not episodically, related to intention stimuli, receive no inhibition (see also Perfect, Moulin, Conway, & Perry, 2002). However, because our design was not ideal to test this hypothesis and responding to new stimuli is qualitatively different from responding to old stimuli, future research is necessary to arrive at definite conclusions on this issue.

3.3. Discussion

The results of Experiment 2 partly replicate and extend the results of Experiment 1. Specifically, as in Experiment 1, results show that forming an intention leads to slower recognition latencies concerning stimuli that are semantically related to the intention stimuli. In addition, the results show that after completing the intention there is no longer a recognition impairment of related stimuli compared to control stimuli. As such these results are consistent with a functional perspective of inhibition of distracting stimuli: As long as an intention must be kept active, distracting stimuli require inhibition. However, once an intention is completed, there is no longer a need for shielding this intention from distraction, and hence inhibition of distracting stimuli is cancelled. These results are complementary with previous research that showed the absence of a special status of completed intentions (Marsh et al., 1998).

4. General discussion

The present experiments yield three important findings concerning the shielding of intentions from distraction. First of all, we have found repeated evidence that forming an intention induces inhibition of information that is related to the content of this intention. This counterintuitive result suggests that intentions are protected from interference by inhibiting stimuli that might interfere with these intentions due to their semantic interrelations. Secondly, results from Experiment 1 point out that this inhibition is targeted very specifically to the episodic representation of related information. This result is discussed more comprehensively below. Finally, data from Experiment 2 illustrates that the inhibition of related stimuli is released after the intention execution. This moderation of the inhibition of related stimuli supports the idea that this inhibition is caused by the potential for distracting stimuli to interfere with active intentions.

Although the present paradigm is based on research on retrieval-induced forgetting, the present inhibition effect is qualitatively different from inhibition of related memory representations after retrieval of a target memory representation. Specifically, in previous research Veling and van Knippenberg (2004) showed that retrieving a target memory representation from long-term memory, by means of category word stem completion (e.g. FRUIT – ma—), induces inhibition of distracting memory representations on both a recognition task (Experiment 1) and a lexical decision task (Experiment 2). This difference in the nature of intention-induced inhibition (III) compared with retrieval-induced inhibition (RII) can be readily explained by considering the manipulations involved in these respective paradigms.

RII concerns inhibition of distracting words during retrieval of words from long-term memory on the basis of cued word stem completion (e.g. FRUIT – ma—). This process may involve either episodic memory, i.e. retrieving a studied word from a previous phase of the experiment (e.g. Anderson et al., 1994), or semantic memory, i.e. retrieving a specific exemplar from a semantic category (see Bäuml, 2002 or Johnson & Anderson, 2004), or both, depending on the strategy of the participant. Hence, word stem completion may lead to inhibition of interfering stimuli in both episodic memory and semantic memory.

The manipulation we used to examine III consisted of asking participants to form an intention to react to a subset of words from previously presented categories. These specific stimuli were not retrieved from long-term memory by the participants, but presented on a computer screen. As a result, there was no reason for participants to search their semantic memory. However, it was important to keep an accurate episodic representation of the intention in mind. To accomplish this, episodic representations that were related to the content of the intention were inhibited in episodic memory.

Because the present research is related to research on the intention superiority effect (Goschke & Kuhl, 1993; Marsh et al., 1998), as it addresses the status of intentional information in memory, it is interesting to compare the present research to research on the intention superiority effect. Consistent with research on intention superiority, both reported experiments indicate that intentions have a special status in memory, because they show that any information distracting with intentional information is inhibited. Furthermore, once an intention is completed, former intentional information is deprived of its special status (see Marsh et al., 1998), as indicated by the disappearance of inhibition of previously distracting information.

A seeming inconsistency with research on intention superiority is that Marsh et al. (1998) found a special status of intentional information in terms of enhanced activation on a lexical decision task towards intentional stimuli, whereas in Experiment 1 we did not obtain any inhibition effect of distracting stimuli on lexical decisions. However, this difference in research outcomes might be explained by considering the difference in the type of intentional information used. Marsh et al. used scripts consisting of related action phrases including both verbs and nouns (e.g. insert the filter, pour the water). Importantly, in their research the intentional content consists of information that is represented in semantic memory, as it is likely that participants, before entering the experiment, have repeatedly performed such actions in their daily lives. Therefore, these intentions may have an episodic representation (memorizing what to do in the beginning of the experiment) as well as a semantic representation (i.e. a more generic representation; e.g. what *pouring water* is). Both these components are relevant for intention execution, and hence activated in memory. In contrast, we used intentions that are entirely new in the sense that participants have never encountered them before. As a result, these intentions can only be stored in episodic memory, and not in semantic memory (O'Reilly and Rudy, 2001). Furthermore, when forming the intention to press the space bar whenever *peach* is presented, generic features of peaches (e.g. round and sweet) are completely irrelevant. Consequently, we neither expected nor obtained effects on a lexical decision task. Future research may investigate inhibitory processes concerning shielding of intentions that are similar to the ones in intention superiority research. We think it is plausible that inhibition of distracting information concerning such intentions operates in both episodic and semantic memory. At present, we like to highlight that the current findings cannot be generalized to all intentions, but apply, at least, to new episodically based intentions such as the one described in the first paragraph of this paper. Hence, the current research gives insight into part of the micro-cognitive processes underlying the shielding of intentions.

On the other hand, research concerning the detection of intentional cues embedded in a background task (i.e. event-based prospective memory) has shown *increased* lexical decision latencies towards intentional stimuli compared with neutral stimuli, when the lexical decision task is the background task (Marsh et al., 2002), and even when accessibility of intention cues is measured with a lexical decision task independent from the background task (Einstein et al., 2005; Experiment 5). In this research domain, increased lexical decision latencies towards intentions cues are interpreted as indicative of spontaneous retrieval of the intention (Einstein et al., 2005) or a preparation to respond (Marsh et al., 2002). The fact that we did not obtain increased lexical decisions towards intentional cues could be due to methodological differences. Specifically, while the current research is similar to research on event-based prospective memory in terms of content of the intention (i.e. specific cues), the procedure is more comparable to research on intention superiority (e.g. Goschke & Kuhl, 1993). As a result, the participants in the current research may have experienced the lexical decision task differently (maybe more independent) than participants in the research from Einstein et al. (2005). However, we like to stress that these methodological differences complicate direct comparisons between the current research and the aforementioned research. Future research might focus on integrating insights from different domains.

The present research indicates that motivation and cognition interact to protect intentions from interference: As long as there is a need to distinguish goal-relevant from goal-irrelevant information, distracting stimuli that might interfere with the content of this intention are targeted by inhibitory processes in episodic memory. As such the current research adds to volitional theories on goal striving by specifying part of the nature and mechanism by which intentions are protected from oblivion.

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