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Attentional Control and Retrieval Induced Forgetting Self-regulation Perspective[1]

Abstract *Retrieval Induced Forgetting (RIF) refers to the finding that the retrieval of some items from memory (RP+) impairs the retrieval of related items (RP-). The RIF effect is indicated by a comparison of RP- with unrelated but also to-be-remembered items (NRP). Since RIF appears during intentional memorizing of words, therefore we checked whether it depends on attentional control (AC) involved in goal maintenance, and also if implicit evaluations of to-be-remembered (RP) contents moderate this process (causing e.g. inhibition). In three experiments, each including AC as the independent variable, we found AC to be related to the RIF effect. Only high but not low AC subjects showed the presence of RIF. The results of the affective priming procedure showed that implicit evaluations of NRP items moderate the relationship of high AC and the RIF effect. The explanation why temporarily devaluated NRP could enhance the RIF effect and suggestion concerning future research summarize the article.*

Key words: *retrieval-induced forgetting, attentional control, goal pursuit, automatic evaluations, inhibition*

Research during the past century has demonstrated that memory works effectively when conscious effort is required; therefore intention and motivation are critical. When one can focus exclusively on material to learn, he or she has got better chance to complete the memory task quickly and accurately. Forgetting, on the other hand, often depends on impaired concentration. When one's attention to information is divided, for example because of distractors, encoding is weaker and later attempts to recall are likely to fail (Craik, Govoni, Naveh-Beniamin,& Anderson, 1996). Practice in retrieving enables longer retention of information during encoding, *ergo* lack of practice causes memory impairment as well. There are many possible causes of forgetting, but one of the most difficult to explain is paradoxical forgetting (impaired recall or recognition) which depends on retrieval of similar items (other items from the same category). For better understanding of retrieval induced forgetting (RIF) we propose a motivational approach to memory explanation. As mentioned, motivation and attention are critical for both encoding and successful retrieval, thus we try to analyze remembering as a goal pursuit and a self-regulation of telic activity.

Memory and Executive Attention

From the motivational perspective, a process is initiated by comparing a goal and a current situation, and is maintained until the decision about its termination is taken (e.g. Carver & Scheier, 1990, Gollwitzer & Bargh, 1996). Personal standards and a social context outline modes of goal-directed self-regulation. From the cognitive perspective, there are executive processes that secure goal attainment. Executive processes "modulate the operation of other processes and they are responsible for the coordination of mental activity, so that particular goal is achieved" (Smith & Kosslyn, 2009, p. 281). Our purpose is to combine motivational and cognitive approaches in order to explain how self-regulation initiated by the "remember as much as possible" goal can produce, together with a structure of the task, paradoxical forgetting (RIF), that we describe in details below.

In recent years researchers have been describing attention as the most activated part of the working memory (WM) (Cowan, 1999, 2010, Engle, Tuholski, Laughlin, & Conway 1999, Oberauer, 2002). The executive attention

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is responsible for sustaining goals and blocking external and internal distractors (namely, irrelevant stimuli and long-term memory representations); therefore, the executive attention has a regulatory function in situations that require the inhibition of competing responses, errors monitoring, and decision-making (Posner & DiGirolamo, 1998). According to Posner (Posner & Rothbart, 1998) there are several attentional systems. The anterior system is viewed as an executive attention system whose functions are described above. It is located in anterior cingulate cortex and interconnected with limbic and frontal motivational systems. What is important, the executive attention can function as the regulator of relatively reactive posterior orienting system. In fact, executive processes refer to controlled attention and working memory, but controlled / executive attention is "an eye and heart" of WM. It is "the kind of selective attention that typically acts on the contents of working memory and direct subsequent processing so as to achieve some goal" (Smith & Kosslyn, 2009, p. 281).[1] Cohen, Aston-Jones, and Gilzenrat (2004) list the following functions of executive attention: (a) maintaining task goals (when activation of their representations must be enhanced to have the desired effect on behavior), (b) updating task goals when conditions are changing, (c) detecting and monitoring conflict, and making adequate control and adjustments in the presence of conflict.

Maintaining and updating task goals directly refers to motivation and affective regulation of telic activity.

Affective Regulation of Executive Attention

Motivational approach provides a new way of understanding the role of automatic processes in goal pursuit. Each episode of goal-directed activity changes the chronic accessibility of semantic memory representations that results from the frequency of recall and importance of specific contents, such as their relevance to the self. Goal motivation shapes the contextual accessibility of representations, i.e. the accessibility of contents that are functionally related to the pursued goal (Higgins, 1996). The underlying mechanism of contextual accessibility differs from that of priming. The effect of priming, for example, with the word *fruit* on the accessibility of *strawberries* and *cherries*, is relatively short and expires with the next stimulation; it is a "pure" mechanism of activation and its decline. (This passive activation of words is also present in the RIF paradigm, where pairs of words beginning with category name are used.)

The review of the research concerning goal-directed activity suggests that *implicit evaluations* increase the accessibility of representations that are functional in terms of the goal (as water for a thirsty person). Therefore, this accessibility is also shaped in an active, motivated manner. Information relevant to goal fulfillment undergoes valuation (becomes positive), and this valuation is maintained until the action completion (Fegusson & Bargh, 2004). This short-lasting change in implicit evaluations includes objects that are useful for goal achievement. The contents that are irrelevant to the task and overload working memory (information noise) are in turn devalued (Roczniewska & Kolańczyk, 2012). This is why shampoo may become a negatively evaluated and rejected liquid when you are thirsty (Brendl, Markman, & Messner, 2003). Valuations and devaluations of goal-referent objects were observed in numerous studies (Ferguson & Bargh, 2004; Custers & Aarts, 2005, Aarts, Custers, & Holland, 2007; Ferguson, 2008; Roczniewska & Kolańczyk, 2012).

Thus, we suggest that positive evaluations in telic activity function as automatic executive processes that shift the marked information into the focus of attention. Simultaneously, negatively evaluated data – hindering and overloading WM – are shifted out from the focus of attention (that is inhibited). If information does not apply to the goal and does not interfere with it, it becomes neutral – neither positive nor negative, and therefore ignored.

Episodic accessibility of affectively marked information differs from its chronic accessibility. It is well documented that encoded positive and particularly negative objects can easily engage our attention. (Peeters &Czapiński, 1990; Lewicka, Czapiński, & Peeters, 1992; Baumeister, Bratslavsky, Finkenauer, & Vohs, 2001). Even if this chronic high accessibility is not as obvious as previously believed (see Rothermund, 2011), negatively evaluated objects definitely engage our attention very fast. By contrast, non-functional and therefore negatively evaluated objects in goal-directed activity are inhibited and excluded from attention. Positive implicit evaluations, indicating objects that are functional in terms of the goal, play a crucial role in executive attention involvement, however only when motivation is strong enough (Ferguson & Bargh, 2004).

Retrieval Induced Forgetting (RIF) as Goal Pursuit Effect

Retrieval-induced forgetting (RIF) refers to the finding that the successful retrieval of a memory trace attenuates the retrieval of rival memory traces. Thus, when certain items from a particular category of words are practiced in retrieval, the retrieval of unpracticed items in the same category is probably suppressed, so that these items actually become harder to retrieve than similar items from a completely unpracticed category. In the RIF paradigm participants are requested to remember as many items as possible, and it is the effect that retrieving memories has on

[1] More detailed relationship between WM and attention are discussed after describing the RIF paradigm.

related memories that unintentionally and unconsciously causes inhibition. This phenomenon was first demonstrated by Anderson, Bjork, and Bjork (1994), who presented their participants with word pairs, each consisting of a category word and an example of an item from that category (e.g. *fruit–banana*). The list contained further items from the same category (e.g. *fruit–apple*), and others from different categories (e.g. *drink–whisky*). Half of the items from certain categories (e.g. *fruit*) were subjected to retrieval practice. When retrieval was subsequently tested for all of the previously untested items, it turned out that unpracticed items from the practiced category gave lower recall scores than those from the unpracticed category. According to the commonly acknowledged interpretation (e.g. Anderson et al., 1994; Anderson, 2003; Racsmany & Conway, 2006; Storm, Bjork & Bjork, 2007) RIF is explained by the inhibitory mechanisms active in the retrieval practice phase between the study and the test, resulting in a temporary deficiency in one's ability to retrieve material stored in memory. However, the automatic blanking of connections between unpracticed exemplars and the names of practiced categories were also considered as an explanation of RIF (because of exclusively reinforced associations between practiced items; Raaijmakers & Shiffrin, 1981; Hulbert, Shivde, & Anderson, 2012).

Retrieval-Induced Forgetting (RIF) Experimental Paradigm.

The classic RIF procedure consists of four stages. (1) In the stage of study the participants get acquainted with pairs of words (e.g. *fruit – apple*) that include category names (e.g. *fruit, vehicle*) paired with a few exemplars each (respectively: *apple, pear; scooter, train*). All pairs are presented in random order and number, at a pace exceeding the possibility of memorizing them all.

(2) The following stage is the retrieval practice (RP) which consists in retrieving only some previously remembered items, and only from the part of the categories, based on a cue (e.g. *fruit – ap*______). (3) Next, in so called distraction phase, the subjects perform a task unrelated in content, which lasts for 10-20 minutes. (4) The last element of the procedure is retrieval – participants are requested to recall or recognize the words presented at the beginning of the experiment (e.g. Racsmany & Conway, 2006). Thus the procedure comprises three sets of pairs of words: (a) practiced pairs: exemplar – category, marked as RP+, (b) non-practiced items from practiced categories – marked as RP- and (c) totally non-practiced pairs: exemplar – category described as NRP. The practiced pairs (RP+) are of course better remembered than non-practiced (RP- and NRP) ones. The RIF indicator is derived from comparing the recall rate of NRP items to that of RP- items, i.e. the subtraction of RP- from NRP **(**Anderson et al,1994; Anderson, 2003; Roman, Soriano, Gomez-Ariza, & Bajo, 2009; Jakab & Raaijmakers, 2009).

Executive Attention and RIF

The attribution of "RIF as inhibition effect" to executive processes is justified in the context of telic memorization. Racsmany and Conway (2006) point out – as we do – that the process of memorizing in the RIF procedure is a telic activity. They also refer to Anderson's (2003) observation, that RIF does not appear without instruction focusing on memorizing. Moreover, individuals who show strong RIF tend to show a lower rate of cognitive failures and forgetfulness in everyday life (Groome & Grant, 2005). These findings indicate that those effective voluntary (goal-oriented) memorizations, that normally need good executive control appear together with RIF. Finally, Aslan and Bäuml's (2011) research indicate that working memory capacity (WMC) correlates positively with the RIF effect. Other authors obtained the same effect in experiments with additional task or an overload with stress during the practice phase (Kato, 2007; Roman et al., 2009; Koessler, Engler, Riether, & Kissler, 2009). RIF disappeared in the situation of WMC limitation. Aslan and Bäuml (2011) explain the significance of WMC for the strength of RIF in categories of resource-consumption by the inhibition of interfering contents (RP-).

If WMC limitations cause disappearance of RIF, then executive attention that depends on WMC could be of strategic importance for RIF. There is a large and consistent body of research to indicate that individual differences in working memory capacity (WMC) reflect basic differences in cognitive control (Engle & Kane, 2004; review in Barrett, Tugade & Engle, 2004). Nevertheless, Unsworth, Redick, Spillers and Brewer (2012) showed that variation in WMC was related to some, but not all, cognitive control operations. WMC was related to active maintenance of the goal measured by response time distributions in Stroop task and antisaccade task. We can say that Stroop task refers to attentional focusing on desired aspects of a word (e.g. color) and thereby to resistance to unintentional shifting to an irrelevant or distracting aspect (meaning). In turn, the antisaccade task demands attentional shifting, i.e. capacity to intentionally switch the attentional focus to a desired object. In this task participants are required to fixate on a central cue, and after a variable amount of time, a flashing cue appears either to the right or to the left of fixation. The participant's crucial task is to shift attention and gaze to the opposite side of the screen as quickly and accurately as possible. Concluding, "overall (…) results are consistent with the notion that high- and low-WMC individuals differ in goal maintenance abilities in which task goals have to be actively maintained" (Unsworth, et al., 2012, p. 348).

Attentional focusing together with attentional shifting have been identified by Derryberry and colleagues as the attentional control related to anterior attentional system (Derryberry & Rothbart,1988; Derryberry & Reeed, 2002). They neglected the last function of executive attention featured by Cohen et al. (2004), i.e. making adequate control and adjustments in the presence of conflict. In turn, Unsworth et al. (2012) noticed a gap in the existing research and examined two indicators of control micro-adjustments. In their experiments the participants' performance (speed and accuracy) in the current trial (trial n) was determined, in part, by what occurred in the preceding trial (n – 1). Post-error slowing, as the indicator of micro-adjustments of control[2], suggested no differences between high- and low-WMC individuals. The authors examined also conflict adaptation effects in the Stroop and flanker task, because in both of these tasks congruent and incongruent trials are intermixed and thus allow for an examination of conflict adaptations. Like in the case of post-error slowing, performance in trial n is here influenced by the amount of conflict present in trial n –1. When there is a great deal of conflict in trial n– 1, performance increases in trial n due to an increase in cognitive control in that trial. High- and low-WMC individuals did not differ in either post-error slowing or conflict adaption effects.

As explained by Unsworth et al. (2012), control micro-adjustment appears when the irrelevant representation passively becomes accessible after priming. It is worth mentioning that passive accessibility is the attribute of non-practiced exemplars from practiced categories (RP-), and therefore RP- should be controlled without involvement of WMC. Nevertheless, involvement of WM is shown as a crucial determinant of RIF (Anderson et al., 1994; Racsmany & Conway, 2006; and others). Since all category exemplars become passively accessible after category priming, those which are not practiced in retrieval must be suppressed (or at least ignored, unless they undergo blanking). Thus, how are we to explain the impact of WMC on the RIF effect (comparison of RP- and NRP) and the RIF itself (relationship between RP+ and RP-)?

Our studies supplement the research on RIF by explaining the role of attentional control and motivational accessibility of memory items. As mentioned above, motivational accessibility differs from the passive one. The involvement of attentional focusing and attentional shifting in pursuit of the "remember as much as possible" goal probably explains part of the RIF effect. The efficient maintaining of the goal needs both attentional focusing (AF) on the goal, and attentional shifting (AS), i.e. transition from one subtask to another without the loss of the main goal criteria. The demands of the task in RIF paradigm are complex, and therefore switching attention from one object or process to another helps the participants to keep attention on a final goal, despite temporary concentration on subtasks.

Affective Regulation of Executive Attention and RIF

If hindering and overloading information is negatively valuated and excluded from the scope of attention (inhibited), then RIF "as an inhibition effect" will manifest in devaluation of unpracticed items from the practiced category (RP-). On the other hand, in accordance with the results of studies on control adjustment, motivational inhibition of RP- consuming WM resources shall not occur. Although such a relationship is possible, the retrieval of RP- is not necessarily related to a distant goal, but mainly to the practice of RP+ and to the adjustment of accessibility conflict after priming. Moreover, by emphasizing only the impact of RP+ on RP-, we neglect other to-be-remembered items in the RIF paradigm, the completely unpracticed (NRP) ones. Are they less disturbing in the retrieval practice phase then RP- items?

Firstly, the main goal "remember as much as possible", makes all pairs of words functional. *Valuations* (positive implicit attitudes) should refer to all items in order to keep them in the scope of attention. Nonetheless, sub-tasks (practice and distraction tasks) make some items functionally inconsistent. When trying to keep in mind RP- and NRP items during the practice phase (involving only RP+), one ought to suppress them for some time. The goal-relevant accessibility of RP- and NRP items could cause their motivational presence in the scope of attention (probably as intrusions for maintaining in memory). Then the overload of WM would require suppression of this information noise via RP- and NRP devaluations.

NRPs are easier to remember because they are chunked into categories (need no division into practiced and unpracticed items). If one controls the goal and tries to keep all items accessible to recall, RP categories are more salient after the practice phase and they seem to be sufficiently represented. Underrepresentation of NRP is easy to notice. The inconsistency of tasks makes NRPs more salient. Also implicit evaluations of categories are more polarized and stronger than evaluations of exemplars, thus more salient (Fiske & Pavelchak, 1986; Dijksterhuis, 2004). Strong, ambiguous evaluations can reinforce memory.

We hypothesize that implicit valuations help to keep all kinds of items in the scope of attention, but temporary devaluations of NRP items can paradoxically reinforce their accessibility after the period of inhibition (Wegner & Erber, 1992). The clear-cut negative implicit evaluation of NRP categories could trigger motivational rebound of previously inhibited items (Liberman & Förster, 2000). Results of a study by Storm, Bjork and Bjork (2007), in which the study phase was repeated after the phase of retrieval practice, support this hypothesis. The inhibited contents are

[2] Consistent with the conflict-monitoring theory these results suggest that following an error, participants slowed down significantly in order to ensure that the subsequent response was correct, therefore engaging in dynamic micro-adjustments of control.

better remembered – the stronger inhibition in the phase of practicing, the stronger accessibility of the contents in the retrieval phase. On the other hand, automatic attenuation of RP- (blanking) or – even more likely – passive control adjustments in the presence of conflict (ignoring accessible exemplars) could be the crucial mechanism of "the pure" retrieval induced forgetting (assuming that RIF means the dependence of RP- forgetting on RP+ retrieval).

Current Studies

Our research begins with the verification of the basic assumption concerning the dependence of RIF on executive attention. Attentional focusing (AF), i.e. intentional directing of attention to desired objects and the resistance of unintentional shifting to distractors or irrelevant objects, is considered as to be responsible for the RIF effect via implicit evaluations. Attentional shifting (AS), i.e. intentional transition of the focus from the main goal (memorization) to other tasks (retrieval of RP+ and completing questionnaires) and back to the goal, is necessary to remember "as much as possible". This is why AS can indirectly determine RIF, the phenomenon which occurs only during goal-directed activity, depending on working memory.

If overload of WM and executive attention produce RIF, then a lot depends on the design of a task. In classical experiments (e.g. Anderson & Spellman, 1995; Anderson et al., 1994; Jakab & Raaijmarks, 2009; Roman et al., 2009) the task causes an overload of executive processes because of: (a) high amount of items (more than 40 pairs of words in six categories), (b) many practice trials (usually each RP+ pair is presented 3 times) extending the duration of the main goal retention in WM, (c) sub-tasks (practice phase and filling in questionnaires). Thus, the question is whether RIF will appear if the number of items and repetitions is smaller? A small number of repetition shortens the time of target stimuli retention in WM, and on the other hand, limits possibility of automatic attenuation of RP- (blanking) or passive adjustments in the presence of conflict (ignoring accessible RP- exemplars). How much is practice and attentional control important for RIF? This question is considered in the pilot study (experiments 1 and 2).

In the experiment 3 we use a typical RIF paradigm (more complex) and verify the hypothesis about the role of attentional control in RIF, as well as the hypothesis about implicit evaluations as automatic attentional controllers.

Pilot Study[3]

Experiment 1 consisted of only one trial of practice, while Experiment 2 of three trials. The scope of the material to be learned was comparable (four categories - two in the practice phase), thus it was possible to compare RIF effects and the role of attentional control in both conditions. Therefore, discussion of the results is presented cumulatively.

Experiment 1

Participants

32 high school students and scouts, aged 16 to 31 (M=19.36; SD=4.4), were invited to participate in the research (sixteen women and sixteen men). The research was conducted in a classroom.

Materials

Stimuli. Words naming four categories of objects and eight exemplars of each category were used as the study material. The ultimate choice included these items which were judged in a preliminary study as the most neutral ones, so that the affect would not modify memorizing. First, five judges were asked to write down some exemplars from each of eight categories. The answers were classified and the words that were most common were excluded in order to eliminate the most typical, and therefore accessible objects. To avoid insufficient diversity of category exemplars, the qualitative analyses were also performed. Next, selected exemplars were evaluated by another fifteen judges. They were asked to mark their assessments on an affective attitudes scale from 1 (*very negative*) to 5 (*very positive*). Finally, only neutral words (whose average mark was not significantly different from 3) were approved for the experiments.

Attentional Control. AC was measured with the Attentional Control Scale (ACS) elaborated by Derryberry and Reed (2002), adapted in Poland by Fajkowska and Derryberry (2010). The first version of ACS, developed by Derryberry and Rothbart (1988) to measure the voluntary attentional focusing and attentional shifting referred to anterior system functioning. These scales were positively correlated with each other and negatively correlated with scales measuring fear, frustration, and sadness (which efficient regulation might be the result of effective attentional control). Validation of the ACS to the anterior function of regulating the posterior orienting was documented several times (Derryberry & Reed, 2002).

In recent studies, the authors combined the attentional focusing and shifting scales to form a measure of Attentional Control. Factor analyses indicated that the scale measured the general capacity for attentional control, with correlated factors relating to the ability (a) to focus attention (e.g., "My concentration is good even if there is music in the room around me"), (b) to shift attention between tasks (e.g., "It is easy for me to read or write while I'm also talking on the phone"), and (c) to flexibly control thought (e.g.,

[3] Experiments 1 and 2 were conducted by Paweł Mordasiewicz.

"I can become interested in a new topic very quickly when I need to"). Since the authors did not use the confirmatory factor analyses, names of factors were formulated *ex post* and they are not fully consistent with factors obtained by Fajkowska and Derryberry (op. cit). In their study the item scores were subjected also to principal-components analyses and from among three factors two appeared to be the same as in previous Derryberry's study – attentional focusing and attentional shifting. The third factor was named 'divided attention' although questions meanings were related to the attentional focus (e.g. "When concentrating, I can focus my attention so that I become unaware of what's going on in the room around me"). Again, authors did not use the confirmatory factor analyses, and there are some doubts about the theoretical validity of the factors. What is more, the data demonstrated that all the items were strong markers of the extracted single factor.

Since we expect an active impact of attentional focusing on RIF and indirect effect of attentional shifting, we have decided to use the original two subscales, each consisting of 10 items (Appendix). First, a theoretical face validity of items in subscales was checked. Although reliability of Polish ACS was satisfactory (α = .88; Fajkowska and Derryberry, 2010), an independent study verifying the reliability of subscales was necessary.

Reliability of Attentional Focus (AF) and Attentional Shifting (AS) Subscals of ACS. The study was conducted by Alina Kamińska (2013). Participants were 200 randomly selected people, 150 women and 50 men. (M = 32.19, SD = 11.42, range 18 – 63 years). As in previous studies, AF and AS subscales were highly correlated (r = .594, p< .0001). The reliability of ACS was slightly lower than in Fajkowska and Derryberry's research (α = .826). Both indicators, AF scale (α = .744) and AS scale (α=.715), were satisfactory.

Procedure

Study phase. The participants were presented with 32 pairs of words which consisted of categories and exemplars, each for 5000 ms, and in random order. They were informed that they should remember all the words because it would be vital for completing the task.

Practice phase. The participants were supposed to complete the category-plus-stem cued recall test: three category names paired with cues (e.g. *fruits - ap___*) were presented in random order. At the beginning of the research half of the items from half of the categories were shown. Each pair was presented only once. If a word stem response was not typed within 7000ms, the next pair was appearing on the screen.

Distraction phase. In this phase participants were completing the Attentional Control Scale and self-control questionnaire, that was not included in the analyses. It lasted for about 10 minutes

Cued recall phase. The subjects were presented with the names of categories and requested to write down all the exemplars presented at the beginning of the experiment. The categories were appearing in random order on the computer screen, and the participants were writing down the memorized exemplars. When they could not recall any more exemplars from a given category, they pressed the button to go over to the next one.

Results

Pearson's correlation of AC with the RIF effect (subtraction of RP- from NRP) was moderate r=.32, p=.039 (one-tailed test), therefore we compared levels of recall in low and high AC groups, which were separated by the median (Mdn=53.5). ANOVA in configuration: 3 (repeated measures of stimulus: RP+, RP-, NRP) x 2 (AC: weak vs. strong) revealed the main effect of the stimulus $F(2,60)=20.29$, p<.0001, η^2 =.413. As shown by the LSD test, RP+ stimuli were better recalled than RP- and NRP (p<.0001). The RIF indicator, that is the difference between NRP and RP-, revealed higher level of NRP recall (p=.046). Despite the fact that no significant interaction between the kind of a stimulus and attentional control was observed (p=.52, η^2= .022) using the LSD test we checked if RIF was present in groups with weak and strong AC. It turned out that only in case of strong attentional control a significant difference (p=.032) between RP- and NRP was observed. Apparently, strong AC is conducive to RIF phenomenon (Fig. 1).

Correlation of AF and the RIF effect was moderate (r=.31 p=.043 one-tailed test), but correlation of AS and the RIF effect was weak and not significant (r=.21). We compared levels of recall in low and high AF and AS groups, which was separated by the medians (AFS Mdn= 25 and ASS Mdn= 28.5). ANOVA in configurations: 3 (stimulus: RP+, RP-, NRP) x 2 (AF weak vs. strong), and 3 (stimulus: RP+, RP-, NRP) x 2 (AS weak vs. strong) was applied. We obtained (a) significant main effects of stimulus (both p<.0001) and significant differences between RP- and NRP (p=.044 and p=.046 respectively); (b) lack of interactions of stimuli with AF (p=.3 ; η^2 =.039) and with AS (p=.49; η^2 =.023); (c) significant RIF (differences between NRP and RP- measured by means of the LSD test) only in case of strong attentional focusing and shifting. The significant difference was observed for strong AF (p=.017) and similarly for strong AS (p=.026) while for weak AF (p=.56) and for weak AF (p=.55) differences were insignificant. We can say that the impact of attentional control on RIF is based on both focus and shifting, although their effects may be different.

Experiment 2

Participants

42 participants of evening classes the Gdansk Culture Center, aged from 16 to 60 (M=23.76, SD=9.43) were invited to participate in the research (twenty four women).

The research was conducted in separate rooms at the institutions premises.

Materials

Stimuli. The participants were presented with the same words as in Experiment 1. However, fillers, i.e. additional category-exemplar pairs, were introduced at the beginning and in the end of study and practice phases, in order to eliminate the influence of primacy and recency effects.

Attentional Control. We used Attentional Control Scale with Attentional Focusing and Attentional Shifting subscales.

Procedure

Study phase was identical with that in Experiment 1.

Practice phase. Each pair of words was presented three times and two pairs of filler category-exemplar stem were introduced at the beginning and two at the end of the task. (Fillers were not included in statistical analyses). If a word stem response was not typed within 7000 ms, the next pair appeared on the screen.

Distraction phase. The subjects completed Attentional Control Scale and a self-control questionnaire, which was not included in the analyses.

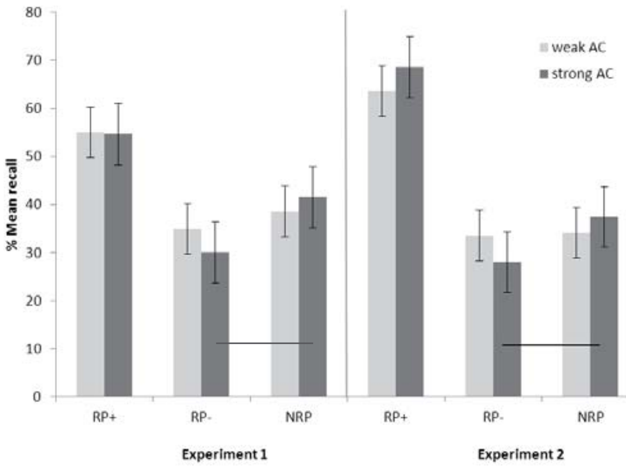
Cued recall phase was the same as in Experiment 1

Results

Correlation of AC with the RIF effect (subtraction of RP- from NRP) was moderate r=.31, p=.023 (one-tailed test), therefore we compared levels of recall in low and high AC groups, separated by the median (*Mdn*=53.5). ANOVA in configuration: 3 (repeated measures of stimulus: RP+, RP-, NRP) x 2 (AC: weak vs. strong) revealed the main effect of the stimulus $F(2,80)$= 63.83, p<.0001, η^2=.615. As the LSD test indicated, RP+ stimuli recall rate was higher than that of RP- and NRP (both p<.0001). The RIF indicator, that is the difference between NRP and RP-, revealed only marginally higher level of NRP recall (p=.099). Although no significant interaction between the type of stimulus and attentional control was observed (p=.26, η^2=. 036), we checked the presence of RIF in groups with weak and strong AC. Again, a significant difference between RP- and NRP (p=.037) occurred only in the group with strong attentional control (Fig. 1).

The results of the first experiment were replicated: once again, it turned out that strong AC was conducive to the RIF phenomenon.

Although the AC subscales played a similar role in determining RIF in Experiment 1, the subtracted impact of AF and AS on RIF was also tested in this experiment. The correlation of AF and RIF was weak (r=.27 p=.044; one-tailed test), similar to the correlation of AS and RIF (r=.29 p=.044). Again, based on the medians of the results in the AFS (*Mdn*=25) and ASS (*Mdn*=28), ANOVA in configurations: 3 (stimulus: RP+, RP-, NRP) x 2 (AF weak vs. strong)



Note: AC – attentional control.
Bars represent +/- 1 SE
Black lines mark significant differences in percentage mean cued recall (RIF effect)

Figure 1. Percentage mean cued recall performance in each practice condition, in groups with weak and strong AC (Pilot study).

or respectively (AS weak vs. strong) was used. We obtained (a) significant main effects of stimulus (both p<.0001) and marginal differences between RP- and NRP (p=.087 and p=.1, respectively); (b) surprisingly, a significant interaction of stimulus and AF (p=.017; η^2=.096), but no significant interaction of AS and stimulus (p=.77; η^2=.0006) and (c) marginal RIF effect (differences between NRP and RP- measured by means of the LSD test) for strong AF (p=.1) and strong AS (p=.1) median-split groups. Weak AF and weak AS groups revealed no RIF, i.e. no significant (p=.42, AF p=.53 respectively) differences between RP- and NRP recall rates.

The results showed the dilution of effects by two weaker factors of AC, and neither of them had a greater share.

Discussion

The pilot study confirmed our hypothesis that RIF depends on attentional control, although the exact contributions of attentional focusing and attentional shifting require further verification. The RIF phenomenon occurred only when attentional control was high. One trial of practice in Experiment 1 produced paradoxically more salient RIF then three trials in the Experiment 2. On the one hand, the participants had less opportunities for automatic attenuation of RP- items by ignoring them (conflict adjustment independent of WM load), and for motivational inhibition by devaluation of NRP and RP-. On the other hand, a short delay of the recall phase (after one trial of practice) enables the control of categories after practice ("Do I still remember everything?"), when AC is strong enough.

Proper Study

The third experiment verified hypotheses about the role of attentional focus and shifting in RIF, as well as the hypothesis about implicit evaluations as automatic attentional controllers. We suppose that strong attentional focus leads to inhibition of motivationally accessible NRP items (possibly also RP-items), via their implicit devaluations during the practice phase. After the inhibition ceasing a rebounding of motivational accessibility of NRP can reinforce NRP memory.

Experiment 3[4]

Experiment 3 is a modified version of Experiment 1 in such a way that conditions correspond to the standard paradigm of RIF experiments (e.g. Anderson et al, 1994; Jakab & Raaijmarks, 2009; Roman et al., 2009). The number of categories was increased to 6, and the number of items ascribed to each category was decreased, also to 6. In consequence the total number of to-be-remembered pairs increased to 40 (36 appropriate, analyzed pairs and 4 pairs of non-analyzed fillers). Moreover, an additional phase was introduced to the procedure – the measurement of implicit evaluation before the retrieval phase.

Participants

44 employees from the companies located at Pomeranian Science and Technology Park, aged from 18 to 50, took part in the research. To guarantee the anonymity of the participants, none of them was asked about age and sex. 4 persons were excluded from the analyses due to the lack of data.

Materials

Stimuli. Taking into account the measurement of implicit evaluations, neutral material was selected in the pilot study. The participants (N = 30) marked on a five-point scale whether a given word was *negative* (1), *slightly negative* (2), *neutral* (3), *slightly positive* (4) or *positive* (5). Objects whose average mark did not significantly differ from 3 were selected for the experiment. Six categories of objects (*pots, clothes, birds, vehicles, furniture, fruit*) containing six neutral items each were selected from 100 estimated words. One category of fillers was added in the research. It gave a total number of 40 stimuli to remember.

Attentional Control. We used Attentional Control Scale with Attentional Focusing and Attentional Shifting subscales.

Implicit evaluations. We measured automatic evaluation by using a sequential evaluative priming paradigm (Fazio, 2001). (a) *Objects (the prime stimuli)*. Previously learned pairs of words with reversed order of a category and an exemplar (e.g. *banana – fruits* instead of *fruits - banana*) were used as the implicit targets of evaluations. An exemplar was exposed on the left side in order to be noticed during a short time of the priming exposure (as more specific than the category). (b) *Adjectives (the target stimuli)*. We used the list of words selected in Roczniewska and Kolańczyk's study (2012): 10 positive adjectives (such as *cheerful* and *friendly*) and 10 negative adjectives (*disgusting, sad,* etc.). (c) *The affective priming procedure.* The primes were pairs of words (exemplars and categories) used in the RIF task and followed by adjectives. The participants were asked to render an evaluative decision ("*Is this a positive or negative word?*") and press the plus (+) key for positive adjectives and the minus (–) key for negative adjectives. The dependent measure was the reaction time toward the adjectives as a function of the type of prime. (The response is facilitated when the prime and target stimuli are affectively congruent, i.e. when a positive object is followed by a positive adjective, or a negative object is followed by a negative adjective. Affective incongruence delays the response; Fazio, Sanbonmatsu, Powell, & Kardes, 1986.) Each trial began with the presentation of a fixation point in the center of the screen (for 500 ms). One of previously learned reversed pairs of words was subsequently presented for 100 ms and followed by an adjective. The adjective remained on the screen until the subject responded to it by pressing the left or the right key of the mouse. The inter-trial interval was 1000 ms. The sequence was repeated for 4 filler pairs presented in the beginning and 36 actual pairs in random order. The adjectives were also rotated through the trials.

Procedure

Study phase. The participants were presented with 40 pairs of words (2 fillers + 36 actual stimuli in random order + 2 fillers) which consisted of categories and exemplars. Each pair was present on the screen for 5000ms. The subjects were informed that they should remember all the words because they would have to retrieve them at the end of the study.

Practice phase. The participants were supposed to complete the category-plus-stem cued recall test. Each pair was presented three times and two pairs of filler category-exemplar stem were introduced at the beginning and two at the end of this task (27 actual trials and 4 filler trials). If a word stem response was not typed within 7000 ms, the next pair would appeared.

Distraction phase was identical as in previous experiments.

Implicit evaluation phase. The questionnaires were followed by an implicit evaluation test, that was described above.

Cued recall phase was the same as in Experiment 1

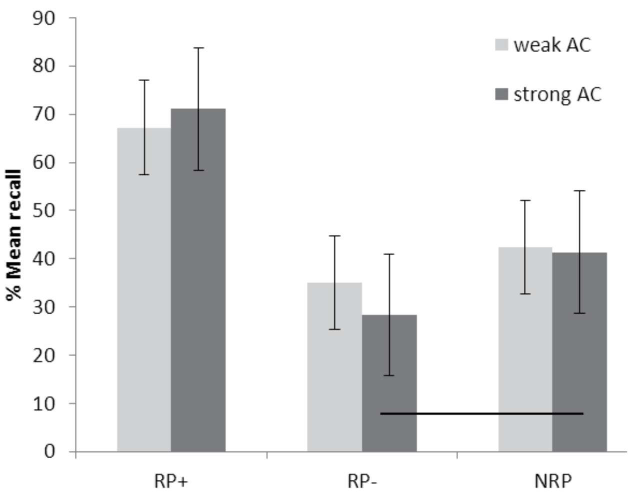
[4] The experiment was conducted by Marta Reszko.

Results

Memory and attentional control

Although correlation of AC with the RIF effect (subtraction of RP- from NRP) was weak *r*=.27, p=.044 (one-tailed test), we compared levels of recall in low and high AC groups, which were separated due to the median (*Mdn*=55). ANOVA in configuration: 3 (repeated measures of stimulus: RP+, RP-, NRP) x 2 (AC: weak vs. strong) revealed the main effect of the stimulus $F(2,70)=90.58$, $p<.001$, $\eta^2=.72$. RP+ stimuli were significantly better retrieved than RP- and NRP (both $p<.0001$), and besides, NRP stimuli were retrieved better than RP- ($p<.001$). The salient RIF effect was obtained for all participants.

Interaction between the kind of stimulus and attentional control was not significant ($p=.18$, $\eta^2=.048$), but as in previous experiments, the RIF effect (the significant difference between RP- and NRP) occurred only in the group with strong AC ($p=.0009$; in group with weak AC $p=.13$) (Fig 2).



Note: AC – attentional control.
Bars represent +/-1 SE
Black line marks significant differences in percentage mean cued recall (RIF effect)

Figure 2. Percentage mean cued recall performance in each practice condition, in groups with weak and strong AC (Experiment 3).

Consequently, we verified also the impact of subscales on the RIF effect. The correlation of AF and RIF effect was weak and not significant ($r=.13$), while the correlation of AS and the RIF effect was moderate ($r=.32$ $p=.02$ one-tailed test).

Based on the medians of the results in the AFS (*Mdn*= 27) and ASS (*Mdn*= 29), for both we used ANOVA in configurations: 3 (stimulus: RP+, RP-, NRP) x 2 (AF weak vs. strong), or respectively: (AS weak vs. strong). The results showed the impact of both factors of attentional control on RIF. We obtained (a) significant main effects of stimulus (both $p<.0001$), and significant RIF (differences between NRP and RP- measured by means of the LSD test; both $p=.002$); (b) significant interaction of stimuli with AF ($F(2, 78)= 3.34$; $p=.04$; $\eta^2=.079$) and insignificant interaction of stimuli with AS ($p=.4$; $\eta^2=.023$.) and (c) significant RIF only in case of strong attentional focusing and shifting. For strong AF $p=.008$ vs. for weak AF $p=.068$, and strong AS $p=.004$ vs. weak AF $p=.14$.

Discussion

Again replication of the results which indicate the impact of attentional control on RIF was obtained; however influences of attentional focus and shifting were less balanced. The results of correlations and of the variance analysis seem to be inconsistent, probably not only due to the labile nature of medians. It is difficult to associate a significant correlation of attentional shifting and the RIF effect with a significant interaction of attentional focus and stimuli. However , the strength of both AF and AS still determines the RIF effect. Nevertheless, this pattern of relationships is promising; according to our hypotheses, attentional focus produces inhibition of NRP via implicit devaluations, while attentional shifting only controls the targets of focus ("hold a rudder"). Therefore, implicit evaluations could mediate influences of AF but not of AS on RIF (then a strong direct correlation of AF with RIF is less necessary).

The role of implicit evaluations in RIF

Our final goal was to verify the hypothesis about implicit devaluations of NRP (and RP- respectively) as the mediator between AF (or possibly AS) and the RIF effect. But first, we checked whether there is a direct impact of affective NRP and RP- (that is evaluation of these kinds of stimuli) on retrieval induced forgetting.

Indicator of affect. The response in the affective priming task is facilitated when prime and target stimuli are affectively congruent, and affective incongruence delays the response. Therefore, the subtraction of reaction time (RT) to positive adjectives from RT to negative adjectives was the indicator of an affect linked to the prime stimuli (RP+. RP- or NRP). If a difference was greater than zero (shorter response to positive associations) then the affect was positive.

The impact of affect on RIF effect. We suspected that NRP would be more clearly inhibited via negative evaluations than RP-, and therefore, better remembered after the inhibition disappearance. Pearson's correlations of RIF effect with implicit evaluations of RP+, RP- and NRP proved to be significant only in the case of NRP ($r = -.365$, $p = .019$). The devaluation of NRP seems to play a very important role in RIF.

Affect as a factor mediating the impact of executive attention on RIF. Finally, the hypothesis about implicit devaluations of NRP as a factor mediating the impact of executive attention on the RIF effect was verified. Simultaneous analysis of regression for the RIF effect and predictors, attentional focusing and affective NRP was conducted; (a) results on the Attentional Focusing Scale, (b) implicit evaluations of NRP as a mediator, and (c) interaction between affective evaluations of NRP and the results on the AF Scale, were introduced as a Cartesian product of these variables (Aiken and West, 1991). We confirmed the hypothesis with the use of Interaction statistical packet 1.7.2211. It is based on a statistically significant model $F(3,37)= 4.403$, $p<.01$ and significant interaction between AF and affective NRP: $t= -2.29$, p=.03; $B=-.002$. In order to interpret this interaction, simple slopes analysis were applied for the low and high evaluations of NRP. Only when affective NRP was low (-1SD), the attentional focusing intensified RIF: $t\ (37) = 2.33$; $p=.013$ (one-tailed test). (Fig. 3)

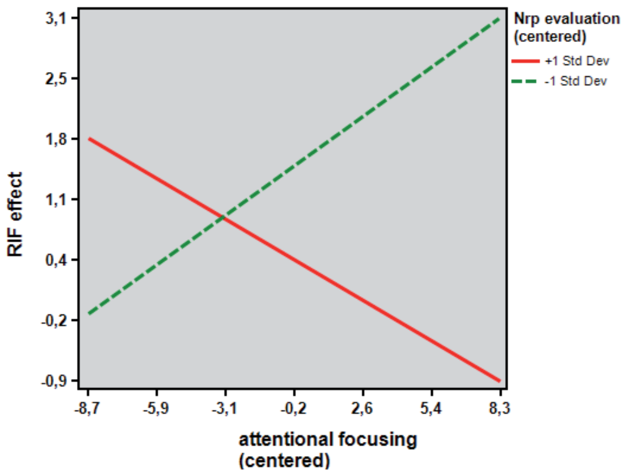


Figure 3. Attentional focusing impact on the RIF effect based on NRP implicit evaluations

Simple slopes analysis for positive (+1SD) and mean NRP evaluations turned out to be insignificant. As expected, low evaluations of NRP determine the dependence of the RIF effect on attentional focusing.

We introduced also the attentional shifting to analyses. In this case, according to our hypothesis no relationship was significant. However, when we used AC analysis instead of AF, we obtained also significant results. Despite the lack of significant influence of attentional shifting on RIF in the case of NRP devaluation, a total impact of attentional control is similar to that of attentional focusing.

The analyses of attention and the RIF effect relation concerning affective attitudes towards RP- items provided no significant results for AF, AS and AC.

Discussion

Albeit we measured implicit evaluations after the distraction phase and before the retrieval phase, our analyses indicate direct and indirect impact of affective NRP on the RIF effect. Negative Pearson's correlation between affective NRP and the RIF effect confirms our hypothesis about NRP devaluation during the practice phase. The strength of devaluations (of generally positive evaluated NRP – due to functionality in the main goal pursuit) should be pronounced even more directly after the practice phase, and we are going to check it in the next study. On the other hand, the continued devaluations are probably responsible for the enhancing of the NRP retrieval.

The strongest support of our hypotheses was provided by the simultaneous analysis of regression for the RIF effect and predictors: attentional focusing (and also shifting) and affective NRP. The attentional focusing (and not shifting) intensified RIF only in the group of participants whose implicit evaluations of NRP were low. This result supports our hypothesis that NRP devaluation depends on the focus on the RP+ practice task, which triggers the inhibition of accessible irrelevant NRP categories. The main goal ("remember as much as possible") automatically enhances accessibility of the NRP items, what turns out to be only temporarily non-functional. Finally, NRP is much better remembered than RP-.

General Discussion

Retrieval induced forgetting (RIF) is one of the most elusive psychological phenomena. It refers to the finding that the retrieval of some items from memory (RP+) impairs the retrieval of related items (RP-), although the RIF effect is indicated by comparison of RP- with unrelated but also to-be-remembered items (NRP). Some authors (e.g., Anderson, 2003; Aslan, & Bäuml, 2011) have suggested that RP- inhibition is the result of a central executive mechanism and the WM capacity. In contrast, others have argued that inhibition in RIF is automatic (Raaijmakers & Shiffrin, 1981; Jakab & Raaijmarks 2009). Our aim in the present study was to further evaluate the inhibitory executive-control explanation of RIF by approaching RIF from an individual-differences perspective (see e.g. Aslan & Bäuml, 2011). Previous work indicates that individuals differ largely in their capability for inhibitory executive control. We explored this issue by proposing a new research approach, considering memorizing in the RIF paradigm as a complex motivational process.

Discussion on relationships between WM and executive attention conducted in our paper showed that RP- exemplars could be ignored (neglected) but not necessarily actively inhibited. According to our speculation derived from the studies of Unsworth etal. (2012), ignoring would be the adjustment of control in the presence of competing RP+ and RP- exemplars, but would not consume WM resources. Ignoring RP- items is not linked to the goal of memorization, but to the practice of RP+ items. This part of theoretical analyses was a side-effect of our research on the function of attentional control (AC) whose aim was the maintenance of a goal-directed activity. Activation of the goal (memorizing as much as possible) make neglected NRP and RP- items during the practice phase irrelevantly accessible. However, NRP items are more salient then these of RP- due to the lack of whole categories, not only expemplars. That is why to-be-remembered NRP items could be maintained in the scope of attention and then motivationally inhibited to a greater extent than RP-items.

First, we verified the hypothesis about the role of AC in RIF. In three experiments conducted in the RIF paradigm, each including AC as the independent variable, we found AC to be related to the RIF effect. Only high but not low AC subjects (median-split groups) showed the presence of RIF. The impact of AC factors (attentional focusing and attentional shifting) did not differ, although we predicted more direct influence of AF than AS on the RIF effect. This difference appeared only after taking into consideration the affective inhibition mechanism.

In Experiment 3 we checked affective regulation of executive attention contents by using affective priming procedure as the measure of implicit evaluations of all RP items. Implicit evaluation in telic activity signals which piece of information is important (positive affect) and which is bothering and should be inhibited (negative affect). Irrelevant and therefore ignored contents are becoming neutral (neither positive nor negative) (Brendl, Markman, & Messner, 2003; Ferguson & Bargh, 2004; Roczniewska & Kolańczyk, 2012; Kolańczyk, 2012). We used implicit devaluation as the indicator of inhibition (when executive processes are overload by a lot of to-be-remembered items). Our hypotheses have been supported by the negative correlation of NRP evaluations with the RIF effect, and the dependence of the RIF effect on the AC intensity only in the group of participants with the lowest implicit evaluations.

How much the RIF effect depends on attentional control and executive attention?

Based on the research on the functions of executive attention (Unsworth et al., 2012), we identified (a) attentional control (focusing and shifting) as responsible for the goal maintenance, and (b) adjustments in the presence of conflict after priming as presumably responsible for "pure" RIF. In fact, although the results showed the dependence of the RIF effect on AC, this relationship does not fully explain the RIF phenomenon. Low AC participants also showed the RIF effect in the third experiment. Maybe they all had relatively high AC, but we can't neglect the fact that a big number of to-be-remembered items limits the possibility of motivational control over them. In that case, conflict adaptation, i.e. ignoring of RP- or their extinction, would play proportionally bigger role. The ratio of mechanisms responsible for RIF would depend on the memorization strategy and the complexity of to-be-remembered material.

Is it correct to use ACS for measuring individual differences in RIF?

The application of the questionnaire instead of the manipulation of AC may be controversial, although ACS was well theoretically and empirically developed on the base of the Derryberry research on AC (e.g. Derryberry & Reed, 2002) and the research on the relationship between WM and executive attention (Unsworth, Redick, Spillers & Brewer, 2012). Even if the theoretical accuracy of ACS were acceptable, the difficult problem of a the retrieval-induced forgetting reliability and stability of individual differences in AC has remained opened. Moreover, findings of Potts, Law, Golding and Groome (2012) suggest that individual differences in RIF performance are not reliable across time. Reduction in the RIF effect was observed e.g. when a negative mood was induced in healthy participants (Bauml & Kuhbandner, 2007). Coherently with this, a significant inverse correlation between RIF and depression was noticed (Groome & Sterkaj, 2010). Therefore, Potts et al. (op. cit) proposed the control for factors such as negative mood that may affect the observed RIF score.

Our experimental data indicate that mood is an inherent factor of the AC Scale. The study conducted by Kamińska (described together with ASC reliability in this article), showed a significant correlation of ACS scores with anxiety STAI scores (Polish adaptation by Wrześniewski, Sosnowski,& Matusik, 2002). In fact, state anxiety correlated with AC significantly but less strongly (N=200, r=-.283; p=.0001) than trait anxiety (N=200; r= -.479; p=.0001). Moreover, before Experiment 1 participants' mood was measured on a five-point scale (1 - *very bad* vs. 5 -*excellent*), and positive correlation with AC was obtained (N=68 r=.298, p=.014). ACS sensitivity to the influence of mood, corresponding to the influence of mood on the RIF effect, justifies the use of this questionnaire in our study.

Future studies. Although with the use of ACS we obtained replication of the results and we believe in impact of AC on RIF effect, the study should be repeated with the use of experimental manipulation of attention. The ACS provides a rather explorative and global view on attentional control, even though it shows a special role of focusing (but not shifting) in the inhibition (NRP devaluation). This proposal must be, of course, experimentally replicated for the full acceptance. The relationship between inhibition and negative evaluations of NRP during the practice phase should be independently demonstrated. It is possible also to check if NRP items during practice phase are particularly accessible.

Moreover, the suggestion about the control adjustment in the presence of competing RP+ and RP- exemplars, i.e. ignoring that depends on executive attention but not on WM, still has the status of a hypothesis. It can be difficult to verify it, considering that the level of NRP (RP- control condition) is changing depending on motivation and attentional control. The only solution is probably a parallel study of the two mechanisms.

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Appendix

Items of the Attentional Control Scale (ACS).

R marked reverse-scored item.
Attentional Focusing (*AF*) Scale and Attentional Shifting (*AS*) Scale are also marked

1. It's very hard for me to concentrate on a difficult task when there are noises around. (R) (*AF*)
2. When I need to concentrate and solve a problem, I have trouble focusing my attention. (R) (*AF*)
3. When I am working hard on something, I still get distracted by events around me. (R) (*AF*)
4. My concentration is good even if there is music in the room around me. (*AF*)
5. When concentrating, I can focus my attention so that I become unaware of what's going on in the room around me. (*AF*)
6. When I am reading or studying, I am easily distracted if there are people talking in the same room. (R) (*AS*)
7. When trying to focus my attention on something, I have difficulty blocking out distracting thoughts. (R) (*AF*)
8. I have a hard time concentrating when I'm excited about something. (R) (*AF*)
9. When concentrating I ignore feelings of hunger or thirst. (*AF*)
10. I can quickly switch from one task to another. (*AS*)
11. It takes me a while to get really involved in a new task. (R) (*AS*)
12. It is difficult for me to coordinate my attention between the listening and writing required when taking notes during lectures. (R) (*AS*)
13. I can become interested in a new topic very quickly when I need to. (*AS*)
14. It is easy for me to read or write while I'm also talking on the phone. (*AS*)
15. I have trouble carrying on two conversations at once. (R) (*AS*)
16. I have a hard time coming up with new ideas quickly. (R) (*AS*)
17. After being interrupted or distracted, I can easily shift my attention back to what I was doing before. (*AS*)
18. When a distracting thought comes to mind, it is easy for me to shift my attention away from it. (*AF*)
19. It is easy for me to alternate between two different tasks. (*AS*)
20. It is hard for me to break from one way of thinking about something and look at it from another point of view. (R) (*AS*)