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FlashReport

Goal-directed processing of self-relevant information is associated with less cognitive interference than the processing of information about other people

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HIGHLIGHTS

- We tested cognitive interference associated with goal-directed self-processing.
- Self-recognition was related to less interference than other-recognition.
- Goal-directed self-processing could easily co-occur with concurrent mental activity.

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ABSTRACT

Goal-directed mental processes focused on oneself often co-occur with goal-directed mental processes focused on other people or objects. However, little is known about the mechanisms of this fundamental type of cognitive interaction. The aim of this study was to determine the degree of cognitive interference associated with self-related processing compared with other-related processing. In two separate experiments, we found that an additional letter-case task interfered with self-recognition significantly less than with the recognition of famous and unknown others. This principal finding was consistent across the accuracy and latency of the participants' responses and across different categories of autobiographical stimuli. Together, these results suggest that the goal-directed processing of self-related stimuli is relatively effortless and that it could easily co-occur with additional mental tasks. Implications for models of access to self-concept and models of cognitive interference are discussed.

1. Introduction

Many situations in everyday life involve an interaction between goal-directed attention focused on oneself and goal-directed attention focused on other people or objects. For example, one can monitor one's own tone of voice or gestures when giving a talk while simultaneously checking the reactions of people in the audience. Surprisingly, the mechanisms of this fundamental type of mental interaction remain largely unknown. In particular, it is unclear whether concurrent goal-directed self-processing and other-processing interfere with each other more or less than two goal-directed other-related mental processes.

To navigate the environment efficiently, people must rapidly select sensory information that is relevant to their current behavioral goals. They must also quickly redirect their attention and change their course of action when faced with novel, potentially threatening, or rewarding stimuli (Corbetta, Patel, & Shulman, 2008). These two types of processes refer to goal-directed and stimulus-driven attention, respectively. Many studies have focused on how sensory-driven (task-irrelevant) self-processing interacts with concurrent behavioral tasks (Alexopoulos, Muller, Ric, & Marendaz, 2012; Bargh & Pratto, 1986; Bundesen, Kyllingsbaek, Houmann, & Jensen, 1997; Gray, Ambady, Lowenthal, & Deldin, 2004; Moray, 1959; Wolford & Morrison, 1980). However, less is known about how goal-directed (task-relevant) self-processing interacts with additional mental tasks.

Automaticity develops as a function of repetition; the more frequently and consistently a mental representation is accessed, the lower its threshold of activation becomes (Bargh, 1994; Schneider & Chein, 2003). In other words, after sufficient training, the representation becomes activated by the mere presence of a trigger, involuntarily, unconsciously, and with minimal cognitive effort. In contrast, controlled processes are intentional, aware, and effortful. Crucially, two controlled mental processes interfere with each other to a greater degree than two automatic processes and more than one automatic and one controlled processes (Bargh, 1994; Moors, 2015; Schneider & Chein, 2003). The most common way of explaining this interference effect is to assume

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that people share processing capacity among mental processes; when more than one process occurs at any given moment, there is less capacity available for each individual process and performance is impaired (Pashler, 1994). Thus, cognitive interference is an indicator of cognitive effort. In the present study, we use this indicator to determine whether goal-directed self-processing is more or less effortless than other-processing (please note that other features of automaticity are outside the scope of this study).

Self-concept refers to one's mental representation of one's own identity, personality, social roles, and values (e.g., Oyserman, Elmore, & Smith, 2012). The abilities to construct and consciously access this representation (e.g., self-recognition or self-reflection) are considered hallmarks of the human mind, as both ontogenetically (Zelazo, 2004) and phylogenetically (Gallup, 1997), these abilities are among the last cognitive functions to develop. Notably, one's own name seems to have a central position in self-concept. The state of namelessness is considered equal to having no social identity (Watson, 1986). Even 5-month-old infants differentiate the sound of their own name from other names (Parise, Friederici, & Striano, 2010), and a preference for the letters in one's own name is regarded as an implicit measure of self-esteem (Gebauer, Riketta, Broemer, & Maio, 2008). Other autobiographical facts, such as one's date of birth, hometown, or nationality, are also crucial components of self-knowledge (Gray et al., 2004). In this study, we use the processing of autobiographical semantic stimuli to determine the degree of cognitive effort associated with access to self-concept.

Because people often refer to their representations of self (e.g., Greenwald, 1980; Greenwald & Banaji, 1989) and because automaticity develops as a function of repetition (see previous paragraphs), access to self-concept should be related to minimal cognitive interference. Indeed, Bargh (1982) showed that repeating aloud self-relevant trait adjectives presented in one ear impairs the performance of a concurrent visual detection task to a lesser extent than repeating self-irrelevant trait adjective does. Similarly, MacDonald and Kuiper (1985) found that better memory performance for self- than for other-related information is unaffected by the presence of an additional cognitive task during encoding. The subject's own name can also be reported with high accuracy even when presented immediately after another target stimulus; in contrast, other names are not noticed under such conditions (Giesbrecht, Sy, & Lewis, 2009; Shapiro, Caldwell, & Sorensen, 1997). The above studies suggest that goal-directed self-processing produces little cognitive interference.

However, self-relevant stimuli are also intrinsically salient (Sui, He, & Humphreys, 2012; Sui, Rotshtein, & Humphreys, 2013); they easily “grab” participants' attention (Bargh & Pratto, 1986; Moray, 1959; Wolford & Morrison, 1980), and they trigger increased attention allocation responses (Tacikowski, Cygan, & Nowicka, 2014; Tacikowski & Nowicka, 2010; Turk et al., 2011). If self-processing engages increased cognitive resources, then according to the capacity-sharing principle, self-processing should produce strong interference with concurrent tasks. Turk et al. (2013) directly supported this claim; the participants in their study categorized objects as belonging to themselves or to another person while attending to or ignoring numbers concurrently displayed on a computer screen. A later memory test showed that divided attention during encoding resulted in decreased retrieval of objects assigned to the self but not objects assigned to another person. Together, these findings suggest that goal-directed self-processing produces strong cognitive interference.

Certain methodological factors could underlie the abovementioned inconsistent findings. For example, simply repeating self-relevant trait adjectives (Bargh, 1982) or detecting one's own name among other stimuli (Giesbrecht et al., 2009; Shapiro et al., 1997) might not involve explicit goal-directed self-processing in the same way that self-reflection or self-recognition do. In turn, measuring the degree of interference in a post-experiment memory test (MacDonald & Kuiper, 1985; Turk et al., 2013) might be confounded by nonspecific factors that occur between the encoding and retrieval phases; such a post-experiment test does not measure interference when it actually takes place. Finally, all-or-none measures of interference, such as reportability or recall (Giesbrecht et al., 2009; Turk et al., 2013), might not be sensitive enough to capture the *degree* of interference associated with self-processing.

The aim of this study is to provide conclusive evidence regarding the degree of cognitive interference associated with goal-directed self-processing. Taking into account the abovementioned methodological issues, we made self-processing explicit and intentional by employing a self-recognition task. In addition, we assessed cognitive interference on a trial-by-trial basis (i.e., at the point when the two cognitive processes actually co-occur), and we used a continuous measure of interference (i.e., reaction times). Our study had a 2 × 2 factorial design with “person” (self vs. other) and “difficulty” (easy vs. hard) as the factors. During the “easy” session, the subjects were asked to determine whether a name, a surname, a birthplace, or a nationality code referred to themselves or to other people. In turn, during the “hard” session, the person-recognition task described above was accompanied by a letter-case task (“Decide whether a target is self- or other-related but only in trials where the targets are written in lowercase letters”). This additional “go/no-go” task had no particular relevance to our main research question; its only role was to compete for cognitive resources with the primary person-recognition task (Fig. 1A). As a result, there were four experimental conditions: self-easy (SE), other-easy (OE), self-hard (SH), and other-hard (OH). Our main dependent variables were error rates (ERs) and reaction times (RTs). We used these variables to calculate the degree of self-interference (S_i) and other-interference (O_i), as the SH > SE and OH > OE differences, respectively.

We hypothesized that if self-processing is more effortless than other-processing, then the letter-case task should impair self-recognition significantly less than it impairs other-recognition, as indicated by the $S_i^{ER} < O_i^{ER}$ and $S_i^{RT} < O_i^{RT}$ differences. In contrast, if self-processing is more effortful than other-processing, then effects in the opposite direction should occur (i.e., $S_i^{ER} > O_i^{ER}$ and $S_i^{RT} > O_i^{RT}$). We tested these alternative hypotheses in two separate experiments conducted with two different groups of participants. In the second experiment, we included a condition that featured famous celebrities rather than unknown others (as was used in the first experiment) to control the effect of sematic familiarity.

2. Experiment I

2.1. Materials and methods

2.1.1. Participants

Twenty-four naïve right-handed subjects (mean age: 26 ± 4 years, fourteen females) participated in this study. All participants were healthy, reported no history of psychiatric illness or neurological disorder, and had normal or corrected-to-normal vision. All participants gave their written informed consent before the start of the experiment. The Regional Ethical Review Board of Stockholm approved the study.

2.1.2. Stimuli and procedure

As experimental stimuli, we used first names, surnames, nationality codes (e.g., “FRA” for France), and places of birth (names of villages, towns, or cities) that were either self- or other-related. All words were written in white letters (“Arial” font) and were presented centrally on a black background. The viewing distance was kept constant for all participants (chin-rest placed 70 cm away from the computer screen). All stimuli in the “self” and “other” conditions had the same number of letters to match the stimuli size.

In the “easy” session, the subjects had to keep track of only one stimulus feature (identity), whereas in the “hard” session, the participants had to pay attention to two features (identity and letter case). All other aspects of stimuli presentation (stimuli, durations, order, etc.)

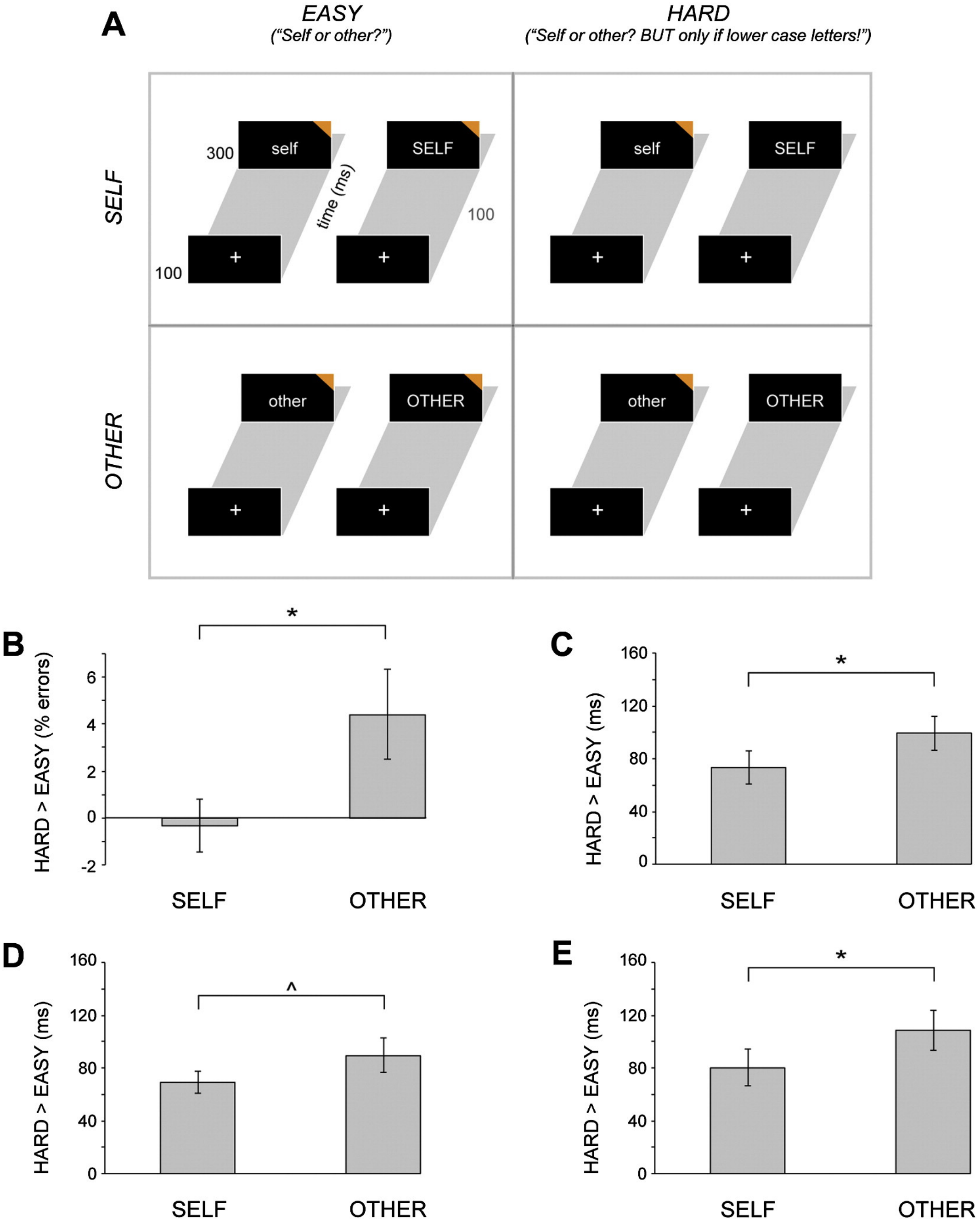

Fig. 1. Design and results of Experiment I. (A) During the "easy" session, the participants discriminated whether names, surnames, places of birth, or nationality codes referred to themselves or to another person. During the "hard" session, the participants performed the same task but only if target words were written in lowercase letters (an additional "go/no-go" task). Orange triangles indicate which targets were task-relevant in which session. Stimuli durations and intervals between stimuli are indicated next to the time axis. After each target, the participants had 1000 ms to respond. The analyses of error rates (B) and reaction times (C) showed that the additional letter case task impaired self-processing significantly less than other-processing. The results were analogous for names and surnames (D) and for birthplaces and nationalities (E). Bar plots indicate means and standard errors; (*) and (^) indicate $p < 0.05$ and $p < 0.1$, respectively. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

were identical in the two sessions (Fig. 1A). The order of sessions was counterbalanced across the participants. The participants used the "CTRL" and "NUM-ENTER" buttons on a standard keyboard to indicate their responses. The buttons were pressed with the left and the right index fingers. The key assignment was counterbalanced across participants. Both the accuracy and the speed of the responses were emphasized in the instructions. Before each session, the participants underwent a practice session (16 trials).

For each condition, the occurrence of names, surnames, nationality codes, and town names was equiprobable. The "easy" and "hard" sessions consisted of 96 trials each (approximately 5 min) and there was a short break between the two sessions (approximately 1 min). Within each session, each trial type was repeated 24 times in pseudo-random order (i.e., not more than three consecutive trials with targets referring to the same person). The inter-trial intervals were 500, 750, or 1000 ms, and these intervals were equally distributed across 96 trials. The stimuli were displayed on an LCD computer screen (DELL S2409W; Dell Inc., Round Rock, Texas, US) with a 60-Hz refresh rate and 1920 × 1080 resolution. Presentation software (version 16.2, Neurobehavioral Systems, Inc., Albany, CA) was used to present the stimuli and to record responses.

2.1.3. Data analysis

For each condition, we calculated the ERs as the percentage of trials with incorrect responses. The RTs were extracted from the correct trials only. After sorting the single-trial RTs according to each trial type, we excluded outliers (i.e., values that were 1.5 inter-quartile ranges above the third and below the first quartile), and we calculated the average RTs for each experimental condition. Notably, the total number of detected outliers was very low (mean = 1 ± 1 trials; min. = 0 trials; max. = 4 trials). To even up the number of trials between conditions (i.e., 48 in the SE and OE conditions vs. 24 in the SH and OH conditions) and to exclude any low-level differences among conditions (i.e., different letter cases), from both sessions we used only the trials in which the targets were written in lowercase letters. In this way, we could analyze behavioral responses to the exact same physical stimuli but associated with different tasks.

Based on the ER and RT data, we calculated the interference scores ("hard" > "easy") separately for the "self" and "other" conditions. We first ran the one-sample *t*-tests (two-tailed) on these interference scores to confirm that our basic manipulation of "difficulty" was effective. We expected more delayed RTs and higher ERs in the "hard" than in the "easy" session (i.e., S_i and O_i significantly higher than zero) and indeed this is what we found (see Table 1). With regard to our main hypotheses, S_i and O_i were then compared to each other using the paired *t*-test (two-tailed). We used the bootstrap method (5000 samples) in these tests; bootstrapping is a robust statistical procedure that does not rely on the normality assumption (Erceg-Hurn & Mirosevich, 2008). These bootstrap *t*-tests were conducted using the IBM SPSS software (version 24, IBM Corp., Armonk, NY, US). In turn, effect sizes (Cohen's *d*) and their 95% confidence intervals (CI) were computed using the "BootES" package with 5000 resamples (Kirby & Gerlanc, 2013). In the above text and in the Supplementary information, we reported all measures, manipulations, and exclusions in Experiment I. The data analysis did not influence the data collection. The sample size was determined based on previous relevant studies (Alexopoulos et al., 2012; Giesbrecht et al., 2009).

2.2. Results

Table 1 presents the ERs and RTs for each condition in Experiment I. The ER data showed that S_i^{ER} was significantly weaker than O_i^{ER} (mean difference = −4.75%; SE = 1.9%; $t_{23} = -2.49$; $p = 0.028$; Cohen's $d = -0.51$; $CI_{low} = -0.84$; $CI_{high} = -0.1$). With regard to the RT data, we found that S_i^{RT} was significantly lower than O_i^{RT} (mean difference = −26 ms; SE = 9 ms; $t_{23} = -2.65$; $p = 0.013$; Cohen's $d = -0.54$; $CI_{low} = -0.99$; $CI_{high} = -0.08$). These results consistently show that the additional letter case task impaired self-processing less than other-processing (Fig. 1B and C), which suggests that goal-directed self-processing is more effortless than the processing of information about other people.

Table 1
Means and standard errors for all conditions in Experiment I.

	RTs			ERs		
	M	SE^	n	M	SE^	n
SE	481	12	24	4.3	0.8	24
OE	530	16	24	3.2	0.7	24
SH	554	16	24	4.0	1.0	24
OH	630	19	24	7.5	1.8	24
S_i	74*	9	24	−0.3	1.1	24
O_i	99*	13	24	4.4*	1.9	24

Abbreviations: ERs — error rates; M — means; n — number of observations, RTs — reaction times; and SE — standard error. The RT data is reported in milliseconds, the ER data in percentages.

* Indicates that the interference score ("hard" > "easy") was significantly higher than zero (one-sample *t*-tests, two-tailed, $p < 0.05$).

^ Indicates that standard errors were based on 5000 bootstrap samples.

One might argue that the above findings were specifically driven by the participants' processing of their own names and not by the processing of self-relevant information in general. Indeed, one's own name occurs countless times in everyday life and thus it could be processed more effortlessly than other types of self-relevant information. To test this possibility, we split our data by names and surnames vs. birthplaces and nationalities. We then compared the S_i^{RT} and O_i^{RT} within these datasets. For names and surnames, we found that S_i^{RT} was marginally lower than O_i^{RT} (mean difference = −20 ms; SE = 10 ms; $t_{23} = -2.07$; $p = 0.055$). For birthplaces and nationalities, S_i^{RT} was significantly weaker than O_i^{RT} (mean difference = −28 ms; SE = 13 ms; $t_{23} = -2.18$; $p = 0.038$). This similar pattern of results for very different types of autobiographical material suggests that the effortlessness of self-processing is a general phenomenon rather than a stimulus-specific one.

Another possible concern about Experiment I is that the effortless processing of self-relevant stimuli was driven by the pre-experimental familiarity of these stimuli rather than by their self-relevant nature per se. Knowing that automaticity develops as a function of repetition (Schneider & Chein, 2003) and that self-relevant stimuli occur very often in one's everyday life, we could not rule out the possibility that familiarity played a role in our findings. In fact, there is an ongoing debate in the literature regarding the role of familiarity in the preferential processing of self-related information (Ma & Han, 2010; Qin et al., 2012; Sui et al., 2012; Tacikowski, Brechmann, & Nowicka, 2013). To address this familiarity issue, we designed a second experiment in which we added a control condition that contained familiar but not self-related social stimuli. More specifically, we included a condition with stimuli that referred to famous celebrities. Based on previous findings showing that preferential self-processing is independent from the stimulus familiarity feature (Sui et al., 2012), we hypothesized that familiarity could not explain our main finding from Experiment I; therefore, we expected that the degree of interference should be still weaker in the "self" than in the "famous" condition. Moreover, in Experiment II, we decided to make the "hard" session even more cognitively demanding than in Experiment I to maximize the effect of cognitive interference and thereby increase the method's sensitivity to putative small differences between the "self," "famous," and "unknown" conditions.

3. Experiment II

3.1. Materials and methods

3.1.1. Participants

Thirty-one naïve right-handed subjects (mean age: 27 ± 7 years, eighteen females) participated in the study. All participants were healthy, reported no history of psychiatric illness or neurologic disorder, and had normal or corrected-to-normal vision. All participants gave their written informed consent before the start of the experiment. The Regional Ethical Review Board of Stockholm approved the study. Because of technical problems (unsaved data), four participants were excluded. One additional participant was excluded because her accuracy rate was too low (only slightly above 50%). The mean age of the remaining twenty-six participants (fourteen females) was 26 ± 6 years.

3.1.2. Stimuli and procedure

To make the discrimination between oneself, a famous person, and an unknown person possible, we had to modify the set of experimental stimuli used in the paradigm. That is, because people usually do not know, for example, the exact birthdates of most celebrities, we used only given names and surnames as experimental stimuli (presented together, given name above surname) in this experiment. For ease of reference, we will still refer to these stimuli as "names." All names were written in white letters ("Arial" font) and were presented centrally on a black background. The viewing distance was the same for all participants (chin-rest positioned 70 cm away from the computer screen).

Before the experiment, we asked the participants three questions about the preselected celebrity: (i) "Do you know this person?"; (ii) "What nationality is this person?"; and (iii) "What is this person's occupation?". We included a given celebrity only if the first answer was "yes" and the following answers were correct; otherwise, we selected another celebrity. The unknown names were chosen randomly; we only made sure that the participants did not know anyone with the same name (none of the participants did). We used only one famous and one unknown name for each participant (this was to match the number of repetitions to the "self" condition), but different famous and unknown names were used for different participants. In addition, the participants' own names and the famous and unknown names were matched in terms of gender and the number of letters.

Each trial started with a cue letter ("a" or "A"), followed by a target name (e.g., "john smith" or "JOHN SMITH"), followed by a blank screen when the participants were supposed to indicate a response (Fig. 2A). Importantly, the letter case of the cue was either congruent or incongruent with the target's letter case. A total of 360 trials were presented in two sessions ("easy" and "hard"), and each session consisted of 180 trials presented for approximately 11 min (with an approximately 2-min break between the sessions). Within each session, each of the 12 trial types (Fig. 2A) was repeated 15 times in random order. The inter-trial intervals were 500, 750, or 1000 ms and were equally distributed across 180 trials. The stimuli were displayed on the same computer screen that was used in Experiment I, using the same software. All aspects of stimuli presentation were identical for the "easy" and "hard" sessions. The

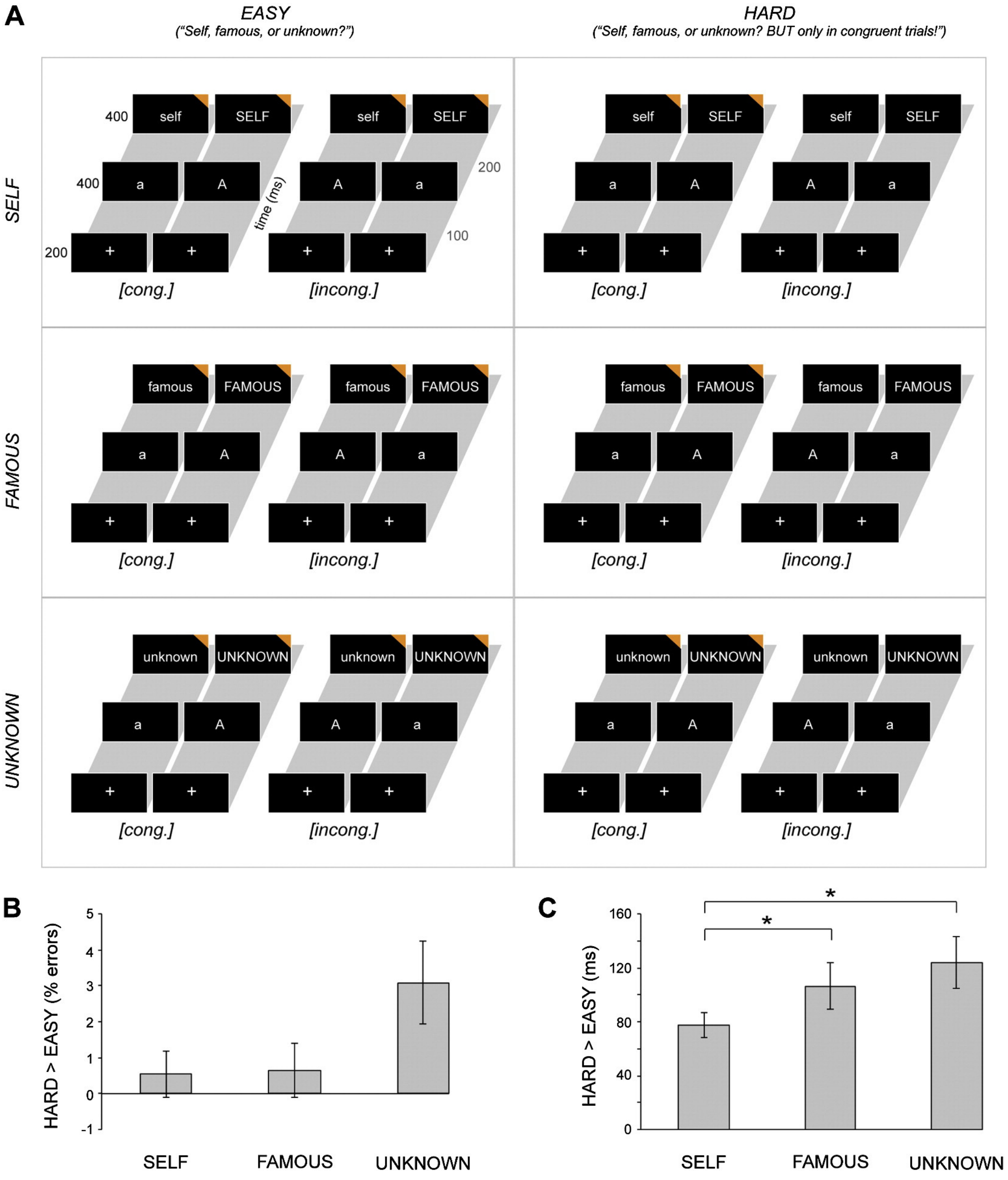

Fig. 2. Design and results of Experiment II. (A) During the "easy" session, the participants discriminated between self-, famous-, and unknown-names regardless of the case of the cue letters. During the "hard" session, the participants performed the same person-recognition task but only if the case of a cue letter was the same as the case of the target-name letters (i.e., congruent trials). Thus, in the "hard" session, the participants had to keep track of the target identity and the cue-target congruency, which changed in every trial. Stimuli durations and intervals are provided next to the time axis. After each target, the participants had 1600 ms to respond. (B) Error rate data did not show any significant effects that would surpass the correction for multiple comparisons (but see the Results section). (C) Reaction time data showed that self-related interference was significantly weaker than unknown- and famous-related interference. Bar plots indicate means and standard errors; (*) indicates $p < 0.05$; all p-values were corrected for multiple comparisons using the FDR method.

order of sessions was counterbalanced across participants. The three arrow buttons on a standard keyboard were used to indicate responses ("left", "down", and "right"). Button presses were made with the index, the middle, and the ring fingers of the right hand. Key assignment (three possible combinations) was counterbalanced across the participants. The instructions emphasized the importance of both the speed and accuracy of the responses. Before each session, the subjects practiced the task (12 trials).

3.1.3. Data analysis

The ER and RT data were analyzed analogously to Experiment I. However, Experiment II had six experimental conditions: "self-easy" (SE), "self-hard" (SH), "famous-easy" (FE), "famous-hard" (FH), "unknown-easy" (UE), and "unknown-hard" (UH). All incongruent trials were discarded from the analysis to match the number of repetitions and physical features between the SE, FE, UE and the SH, FH, UH conditions (see Experiment I). Outliers were detected and removed using the same procedure as in Experiment I (mean = 1 ± 1 trials; min. = 0 trials; max. = 6 trials). Self-interference (S_i), famous-interference (F_i), and unknown-interference (U_i) were calculated for the ER and RT data as the SH > SE, FH > FE, and UH > UE differences, respectively. We used the same statistical procedures that were described in Experiment I. However, because we planned to test all possible contrasts (i.e., S_i vs. F_i, S_i vs. U_i, and F_i vs. U_i), we had to correct for the increased probability of type I error resulting from performing multiple comparisons. To this end, we used the False Discovery Rate approach (Benjamini & Hochberg, 1995) implemented in the "R" software (The R Foundation for Statistical Computing; version 3.2.1 GUI 1.66; https://www.r-project.org). In the above text and in the Supplementary information, we have reported all measures, manipulations, and exclusions in Experiment II. The data analysis did not influence the data collection. The sample size was determined based on Experiment I.

3.2. Results

Table 2 shows the ERs and RTs for all conditions in Experiment II. For the ER data, we found that S_i^{ER} and F_i^{ER} did not differ significantly (mean difference = −0.12%; SE = 0.9%; $t_{25} = -0.13$; $p_{\text{uncorrected}} = 0.9$; $p_{\text{corrected}} = 0.9$; Cohen's $d = -0.04$; $CI_{\text{low}} = -0.43$; $CI_{\text{high}} = 0.37$). Similarly, the difference between S_i^{ER} and U_i^{ER} was not significant (mean difference = −2.54%; SE = 1.3%; $t_{25} = -1.87$; $p_{\text{uncorrected}} = 0.07$, statistical trend; $p_{\text{corrected}} = 0.11$; Cohen's $d = -0.37$; $CI_{\text{low}} = -0.76$; $CI_{\text{high}} = 0.07$) and the difference between F_i^{ER} and U_i^{ER} was also not significant (mean difference = −2.42%; SE = 1.1%; $t_{25} = -2.1$; $p_{\text{uncorrected}} = 0.06$, statistical trend; $p_{\text{corrected}} = 0.11$; Cohen's $d = -0.39$; $CI_{\text{low}} = -0.72$; $CI_{\text{high}} = 0.01$). Notably, although the difference between S_i^{ER} and U_i^{ER} did not surpass the correction for multiple comparisons, the uncorrected p-value approached significance ($p = 0.07$) and the effect was in the same direction as in Experiment I (compare Figs. 1B and 2B).

For the RT data, we found that S_i^{RT} was significantly lower than F_i^{RT} (mean difference = −29 ms; SE = 12 ms; $t_{25} = -2.46$; $p_{\text{uncorrected}} = 0.032$; $p_{\text{corrected}} = 0.048$; Cohen's $d = -0.48$; $CI_{\text{low}} = -0.79$; $CI_{\text{high}} = -0.09$) and that S_i^{RT} was significantly lower than U_i^{RT} (mean difference = −46 ms; SE = 14 ms; $t_{25} = -3.19$; $p_{\text{uncorrected}} = 0.009$; $p_{\text{corrected}} = 0.027$; Cohen's $d = -0.63$; $CI_{\text{low}} = -0.93$; $CI_{\text{high}} = -0.27$). 0.27). The difference between F_i^{RT} and U_i^{RT} was not significant (mean difference = −17 ms; SE = 15 ms; $t_{25} = -1.12$; $p_{\text{uncorrected}} = 0.29$; $p_{\text{corrected}} = 0.29$; Cohen's $d = -0.22$; $CI_{\text{low}} = -0.59$; $CI_{\text{high}} = 0.22$). Together, these results support the main conclusion from Experiment I that self-processing is more effortless than other-processing. Additionally, Experiment II showed that controlling the familiarity feature did not eliminate the effect of lower interference associated with self-processing.

Table 2
Means and standard errors for all conditions in Experiment II.

	RTs			ERs		
	M	SE^	n	M	SE^	n
SE	544	13	26	1.6	0.5	26
FE	606	17	26	2.4	0.5	26
UE	596	15	26	2.3	0.7	26
SH	622	16	26	2.2	0.6	26
FH	712	24	26	3.1	0.8	26
UH	720	23	26	5.5	1.1	26
S_i	78*	9	26	0.5	0.6	26
F_i	106*	17	26	0.7	0.8	26
U_i	124*	19	26	3.1*	1.1	26

Abbreviations: ERs – error rates; M – means; n – number of observations, RTs – reaction times; and SE – standard error. The RT data is reported in milliseconds, the ER data in percentages.

* Indicates that the interference score ("hard" > "easy") was significantly higher than zero (one-sample t-tests, two-tailed, $p < 0.05$).

^ Indicates that standard errors were based on 5000 bootstrap samples.

4. Discussion

The aim of this study was to determine the degree of cognitive interference associated with goal-directed self-processing. In Experiment I, we showed that the additional letter case task interfered less with self-recognition than with the recognition of other people. In Experiment II, we reproduced this principal finding while controlling for possible differences in familiarity between the "self" and the "other" condition. These results indicate that goal-directed self-processing could effectively co-occur with concurrent goal-directed cognitive processes. Below, we discuss our findings regarding models of access to self-concept and models of cognitive interference.

Our results support the notion that access to self-concept is highly efficient. Self-concept has long been proposed to act as a "reference point" in countless cognitive, emotional, and motivational processes during everyday life (Greenwald, 1980; Greenwald & Banaji, 1989). Automaticity develops as a function of repetition; thus, access to self-concept was proposed as automatic (Bargh, 1982; Greenwald, 1980; Greenwald & Banaji, 1989; Pelham, Carvallo, & Jones, 2005). Such automaticity would have two consequences. First, if self-processing is irrelevant to the current behavioral goal, then automatically triggered self-processing should require active inhibition and thus would "steal" cognitive resources from the primary task. This distracting effect of self-processing has been extensively studied and largely confirmed (Bargh & Pratto, 1986; Moray, 1959; Nuñez, Casey, Egner, Hare, & Hirsch, 2005; Wolford & Morrison, 1980; Wood & Cowan, 1995), although important limitations of this effect have also been reported (Bundesen et al., 1997; Devue, Laloyaux, Feyers, Theeuwes, & Brédart, 2009; Gronau, Cohen, & Ben-Shakhar, 2003; Harris & Pashler, 2004; Kawahara & Yamada, 2004). The second prediction of self-automaticity is that if self-processing is relevant to the current behavioral goal, then self-processing should improve performance in a concurrent task because the effortlessness nature of self-processing would enable more cognitive resources to be directed toward a concurrent task (Bargh, 1982). In light of the previous inconsistent findings (see the Introduction), the current study provides important support for this second prediction regarding self-automaticity.

It is important to ask what actually makes self-processing effortless. High frequency of occurrence is one possible factor (Greenwald & Banaji, 1989; Symons & Johnson, 1997), but other factors could also play a role. For example, self-related and other-related mental processes seem to engage separate computational workspaces in the brain (Keenan, Nelson, O'Connor, & Pascual-Leone, 2001; Kircher et al., 2000; but see Gillihan & Farah, 2005). If that is the case, these two types of processes would never compete with each other to the same extent as two other-related or two self-related processes. Such a computational separation would explain why self-recognition engages attentional resources preferentially (Tacikowski & Nowicka, 2010;

Tacikowski et al., 2014) but still produces little cognitive interference with additional non-self-related tasks (the current study).

Along these lines, the neurocognitive model formulated by Dixon, Fox, and Christoff (2014) seems to provide some additional clues regarding why self-processing sometimes strongly interferes with additional mental tasks (Turk et al., 2013) but produces little cognitive interference in other situations (e.g., the current results). This model proposes that (i) internally and externally driven modes of cognition engage partly separate and partly overlapping brain networks and (ii) these two modes of cognition compete with each other only when they both involve a high level of intentional control; otherwise, they could co-occur with minimal interference or even facilitate one another. It is noteworthy that in the present study, we manipulated only the content (self vs. other), not the source (internal vs. external), of information processing and that these two classifications are orthogonal to each other (Lieberman, 2007). Nevertheless, just like internally and externally driven cognition, self-processing and other-processing could involve partly distinct and partly common neural networks and the two types of processes could interfere with each other only when they are both cognitively effortful (e.g., during a difficult working memory task). This interesting hypothesis could be directly tested in future neuroimaging studies. In general, the relationship between self-processing and other-processing appears more complex than previously assumed. More studies are needed to shed light on this fundamental type of mental interaction.

The relationship between self-processing and other-processing has potentially interesting implications for models of cognitive interference. As mentioned in the Introduction, one way of explaining interference is through limited capacity resources. Another view is that some mental operations require a single dedicated mechanism and when two tasks need this mechanism at the same time, a bottleneck results, and one or both tasks become delayed (Pashler, 1994). Interestingly, neither “capacity-sharing” or “bottleneck” theories have established whether resources/bottlenecks are unitary or not (Kahneman, 1973; Pashler, 1994; Wickens, 2002). If self-processing engages attention preferentially, and if self-processing produces little cognitive interference with other-related tasks, then this would suggest that multiple resources/bottlenecks exist.

Regarding the ongoing debate about the nature of cognitive automaticity itself, we interpret our results in relative terms. As recently reviewed by Moors (2015), one view is that automaticity is an all-or-nothing phenomenon and that there is a perfect agreement between different features of automaticity (a given process is unintentional, unaware, effortless, and uncontrollable or intentional, aware, effortful, and controllable). Another view is that automaticity is a gradual phenomenon and that different features of automaticity are partly independent from each other. In line with the gradual view, which seems more grounded in social psychology research (Bargh, 1994; Moors, 2015), we think that self-processing in our study was probably not completely effortless, but it was certainly *more* effortless than other-processing.

The results of Experiment II imply that familiarity per se was not the main driving force in our study. Our RT data showed that (i) self-related interference was still weaker than famous-related interference and (ii) the difference between the “famous” and “unknown” conditions was not significant. These two pieces of evidence taken together suggest that lower interference in the “self” than in the “other” condition could not be reduced to a simple familiar vs. unfamiliar difference, this notion is consistent with previous studies (Ma & Han, 2010; Qin et al., 2012; Sui et al., 2012). On the other hand, F_i^{ER} seemed weaker than U_i^{ER} (Fig. 2B) and, strictly speaking, the non-significant F_i^{RT} vs. U_i^{RT} difference is statistically inconclusive. Besides, additional measures in Experiment II indicated that familiarity associated with famous others was relatively low when compared to close others, which suggests that perhaps we did not cover the whole spectrum of familiarity in the “famous” condition (see Supplementary Information). Future studies are needed to further dissociate the effects of self-relevance and familiarity.

As a methodological clarification, we should mention that the difference between the “easy” and “hard” sessions in our studies was a matter of one vs. two rules governing a single behavioral response. In contrast, classical dual-task interference paradigms typically involve multiple behavioral responses or task switching (Pashler, 1994). In addition, we measured how the letter case task interfered with person-identification and not the other way around. Thus, we can only speculate that the same pattern of results would occur in a task in which participants are asked to indicate the letter case, but only when a target refers to themselves. More research is needed to reveal the full picture of self-related interference across different experimental manipulations.

In sum, the present study suggests that the goal-directed processing of self-relevant information is related to less cognitive interference than the processing of information about other people. Explaining the interplay between self-oriented and world-oriented mental processes is a key to reveal the cognitive architecture of the human self. Apart from fundamental theoretical questions, this interplay is important to explain a number of practical situations, for example, attention lapses in healthy individuals or in people with attention deficits.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at http://dx.doi.org/10.1016/j.jesp.2016.05.007.

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