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On Stopping Yourself:

Self-Relevance Facilitates Response Inhibition

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Abstract

It is well documented that stimuli associated with the self are easier to process than identical material paired with other people (i.e., self-prioritization effect). Surprisingly, however, relatively little is known about how self-relevance impacts core aspects of executive functioning, notably response inhibition. Accordingly, here we used a stop-signal task to establish how effectively responses toward self-relevant (vs. other-relevant) stimuli can intentionally be inhibited. In the context of personal possession, participants were required to classify stimuli (i.e., pens & pencils) based on ownership (i.e., owned-by-self vs. owned-by-friend/stranger), unless an occasional auditory tone indicated that the response should be withheld. The results revealed the benefits of self-relevance on response inhibition. Compared with items owned by a friend or stranger, responses to self-owned objects were inhibited more efficiently. These findings confirm that self-relevance facilitates executive control.

Keywords: self, response inhibition, ownership, executive control

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It is widely accepted that the self influences core aspects of psychological functioning (Baumeister, 1998; Conway & Pleydell-Pearce, 2000; Heatherton et al., 2004; James, 1890; Kilhstrom & Klein, 1994; Markus & Nurius, 1986). Take, for example, self-control, a topic that has spawned extensive theoretical and empirical activity (Baumeister & Heatherton, 1996; Duckworth, & Steinberg, 2015; Sullivan et al., 2015). While some researchers have focused their efforts on understanding how people suppress actions and thoughts to advance their long-term goals and objectives (e.g., Ariely & Wertenbroch, 2002; Fujita et al., 2006; Mischel et al., 1996; Tice et al., 2007), others have concentrated on utilizing self-regulatory performance as a predictor of personal and societal outcomes (e.g., weight gain, adultery, education performance, gambling issues; Hirsh & Inzlicht, 2010; Nederkoorn et al., 2010; Pronk et al., 2011; von Hippel et al., 2009). In addition, research has attempted to identify the processes that determine whether bouts of self-control result in success or failure (e.g., Berkman, Hutcherson et al., 2017; Inzlicht et al., 2014; Muraven & Slessareva, 2003; Sharma et al., 2014). Notwithstanding this extensive body of work, however, several unresolved issues remain. In particular, does the personal significance of material influence the efficiency of executive control — specifically, the intentional stopping of responses?[1] We explored this matter in the current experiment.

Recently, Sui et al. (2012) demonstrated that once an association has been forged between arbitrary stimuli (e.g., geometric shapes) and the self (vs. other people), these items benefit from enhanced processing, a phenomenon dubbed the *self-prioritization effect* (e.g., Schäfer et al., 2015; Schäfer et al., 2016; Wang et al., 2016; Woźniak & Knoblich, 2019). Comparable advantages also emerge through personal possession, such that self-owned objects are identified more rapidly than

[1] Although self-control and executive functioning differ in many ways they both entail response inhibition, which is the focus of the current investigation. Accordingly, here we use the term 'executive functioning/control' to refer to the top-down, goal-directed inhibition of behavior (Nigg, 2017).

identical items owned by others (Constable et al., 2019; Golubickis et al., 2018). Although the bulk of research on this topic has focused on visual and cognitive outcomes (e.g., Constable et al., 2019; Macrae et al., 2017, 2018; Truong et al., 2017; Yankouskaya, Palmer et al., 2017), an interesting line of inquiry has explored the action dynamics of personal possession, revealing that hand-object interactions (e.g., grasping, placement, acceleration) are facilitated through ownership. In other words, visuomotor processing is enhanced when people interact with self-relevant (vs. other-relevant) objects (Constable et al. 2011, 2014). What remains to be seen, however, is whether response inhibition is facilitated by the self-relevance of stimuli in a similar way.

Sui and Humphrey’s (2015) Self-Attention Network (SAN) model has been valuable in guiding work on self-prioritization. On the basis of extensive behavioral and imaging research, it has been suggested that the self operates as a central processing hub, facilitating the binding of information during perception and memory (Humphreys & Sui, 2016). Specifically, increased coupling strength between brain regions responsible for self-representation (i.e., ventral medial prefrontal cortex, vmPFC) and social attention (i.e., posterior superior temporal sulcus, pSTS) enhances the social salience, hence processing, of self-relevant material. A recent theoretical extension by Sui and Rotshtein (2019) has further argued that, to ensure adaptive functioning in complex environments, self interacts with the attentional systems that underpin orienting, alerting and, importantly, executive control (Petersen & Posner, 2012; Posner & Petersen, 1990; Posner et al., 2016). While evidence derived from patient data and imaging studies lends some support to the idea that self-referential processing facilitates executive control (De La Vega et al., 2016; Northoff & Bermpohl, 2004; Sui & Gu, 2017; Sui, Chechlacz et al., 2015; Sui, Enock et al., 2015; Yankouskaya, Humphreys et al., 2017), effects of this kind have yet to be demonstrated in the laboratory tasks that have dominated research on this topic over the last decade (Constable et al., 2011, 2014; Falbén et al., 2019, 2020; Golubickis et al., 2018, 2019, in press; Sui et al., 2012, 2015). Accordingly, to address this issue, here we adapted an object-ownership task to explore the effects of self-relevance on a key component of executive control — response inhibition (Diamond, 2013; Friedman & Miyake, 2004).

Response inhibition has been studied extensively, with the dominant experimental methodology comprising a stop-signal task (Verbruggen & Logan, 2008). In this task, participants make judgments (i.e., a speeded motor response) to a target stimulus (i.e., Go signal). Critically, however, on some trials a stop signal (e.g., auditory tone) appears after stimulus presentation, indicating that participants should attempt to withhold their response. Importantly, this signal appears after a variable delay (i.e., stop-signal delay, SSD), such that at short SSDs stopping a response is relatively easy (i.e., successful inhibition, the action is suspended), whereas at longer delays it is difficult (i.e., failed inhibition, the action is performed). It has been suggested that a horse-race model, comprising two independent processes (i.e., Go & Stop) with stochastically autonomous finishing times, can account for performance in this task. Crucially, the model enables estimation of the covert latency of the stop process — the stop-signal response time (SSRT, see Logan & Cowan, 1984; Logan et al., 1984). In other words, the efficiency of response inhibition can be established.

In the current experiment, we explored the ease with which responses to self-relevant (vs. other-relevant) stimuli could intentionally be stopped. Using a standard stop-signal task in conjunction with a manipulation of object ownership (Falbén et al., 2019, 2020; Golubickis et al., 2018, 2019, in press), participants were presented with items (e.g., pens and pencils) that ostensibly belonged to them (i.e., self) and either a friend or a stranger. In a modified object-ownership task, participants were required to categorize the objects according to ownership (i.e., owned-by-self vs. owned-by-friend/stranger), as quickly and accurately as possible (i.e., Go trials), unless an auditory tone signaled that the response should be withheld (i.e., Stop-Signal trials). Biases for self-relevant information are always expressed in relation to other social targets (e.g., self vs. friend, self vs. famous politician, self vs. stranger; Sui et al., 2012). At least in the memory domain, processing is routinely advantaged when the self is compared with a non-intimate other (e.g., celebrity) or complete stranger. In contrast, when the target of comparison is an intimate other (e.g., parent, friend), the benefits of self-relevance are sometimes reduced (Symons & Johnson, 1997). Accordingly, given these reported findings, both friend (i.e., intimate other) and stranger (i.e., non-intimate other) were selected as targets of comparison in the current experiment to comprise a between-participants replication of the effects of interest (Golubickis et al., 2018; Sui et al., 2012). Based on the contention that self-relevance facilitates the attentional operations that underpin executive control (Sui & Rotshtein, 2019), we hypothesized that inhibition (SSRTs) would be enhanced when the to-be-stopped responses pertained to self-owned compared to other-owned objects.

Method

Participants and Design

Sixty-eight undergraduates (15 males, M_{age} = 23.09, *SD* = 6.04) took part in the research.[2] Six participants (1 male) failed to follow the instructions, thus were excluded from the analysis. In addition, one participant (female) was excluded due to software issues (i.e., data were not saved). Informed consent was obtained from participants prior to the commencement of the experiment and the protocol was reviewed and approved by the Ethics Committee at the School of Psychology, University of Aberdeen. The experiment had a 2 (Owner: self vs. other) X 2 (Target of Comparison: friend vs. stranger) mixed design, with repeated measures on the first factor.

Stimulus Material and Procedure

Participants arrived at the laboratory individually, were seated in front of a desktop computer, and told the experiment comprised an object-categorization task featuring pens and pencils (Golubickis et al., 2018). Prior to the commencement of the task, participants were told that the experimental software (Matlab) would randomly allocate one set of items (either pens or pencils) to be owned by them (i.e., self-owned) and the other set to be owned by another person (i.e., other-owned). For half the participants, the target of comparison was their best friend (i.e., self-owned vs. friend-owned), and at this point individuals were asked to name their friend; for the others, it was an arbitrary

[2] Based on Golubickis et al. (2018), PANGEA (v.0.2) (d = .50, α = .05, power = 80%) indicated a requirement of 34 participants in each between-participants condition.

stranger (i.e., self-owned vs. stranger-owned). Next, after a button press (a spacebar), text appeared on the screen indicating which class of objects had been assigned to the participant and other person (i.e., friend or stranger), respectively (e.g., you = pencils, friend/stranger = pens). Participants were then informed that, on the computer screen, they would be presented with individual pictures of pens and pencils and their task was to report (via a button press), as quickly and accurately as possible, whether the items belonged to them or the other person. Responses were given using two buttons on the keyboard (i.e., N & M). The key-response mappings and assignment of objects to self and other were counterbalanced across participants. The labels ‘mine’ and ‘friend’ or ‘stranger’ were located on the screen on the same side as the associated buttons on the keyboard. Critically, participants were also informed that, on certain trials (i.e., Stop-Signal trials), an auditory tone would indicate that they should withhold their response (i.e., do not press the button). Participants were instructed not to wait for the auditory tone in order to avoid strategic slowing (Verbruggen et al., 2013).

Following Golubickis et al. (2018), each trial began with the presentation of a central fixation cross for 500 ms, followed by a picture of a pen or a pencil which remained on the screen for 100 ms. The screen then turned blank and a response was required within 1000 ms. All stimuli were presented in the center of the screen on a white background. The stimulus set comprised pictures of 16 pens and 16 pencils (140 x 140 pixels), all in greyscale and matched for luminance. Participants performed 16 practice trials, followed by four experimental blocks, each with 128 trials, in which all stimuli occurred equally often in a random order. After each block, participants received feedback about the number of errors committed and the mean reaction time. In total, there were 512 experimental trials with 256 trials in each condition (i.e., self-owned vs. other-owned) with a stop-signal occurring on 25% of the trials. The stop signals were 1000 Hz tones presented for 100 ms and occurred dynamically. Specifically, stop-signal delays (SSDs) were adjusted according to separate staircase tracking procedures that allowed the SSD value to converge individually for each participant, thus enabling it to be used as a dependent measure. Each time a participant successfully inhibited the response, the SSD increased by 50 ms. If, however, a participant failed to inhibit the response, the SSD decreased by 50 ms. The SSD values were drawn from four interleaved staircases of which two (i.e., one for self-owned and another for other-owned) started at 250 ms (i.e., easy to inhibit) and the other two commenced at 450 ms (i.e., difficult to inhibit). This resulted in 32 trials from each staircase for a total of 128 stop trials. The experiment took approximately 20 minutes to complete. Stimulus and response events were presented using Matlab (Mathworks) and the Psychtoolbox (www.psychtoolbox.org). On completion of the task, participants were debriefed, thanked, and dismissed.

Results

To explore the effects of ownership on object categorization during a stop-signal task, a 2 (Owner: self vs. other) X 2 (Target of Comparison: friend vs. stranger) mixed model analysis of variance (ANOVA) was conducted on participants' mean Go response times (Go RTs), response accuracy, SSDs, failed inhibition, and SSRTs, the results of which are summarized in Appendix A.[3]

Go RTs. Responses faster than 200 ms were excluded from the analysis, eliminating less than 1% of the overall number of trials. The only effect to emerge in the analysis was a main effect of Owner ($F(1, 57) = 32.13$, $p < .001$, $\eta_p^2 = .360$), such that responses were faster to self-owned ($M = 600$ ms, $SD = 111$ ms) compared to other-owned ($M = 637$ ms, $SD = 112$ ms) items (see Figure 1, upper panel).

Accuracy. The analysis yielded only a main effect of Owner ($F(1, 57) = 10.40$, $p = .002$, $\eta_p^2 = .154$), indicating that responses were more accurate to self-owned ($M = 96\%$, $SD = 4\%$) compared to other-owned ($M = 92\%$, $SD = 7\%$) items.

SSDs. As the SSD values were adjusted based on individual performance (i.e., failed/successful inhibition decreased/increased SSD by 50 ms), the average across both easy and difficult staircases (i.e., 64 stop signal trials) was calculated for each ownership condition. The analysis revealed only a main effect of Owner ($F(1, 57) = 12.18$, $p < .001$, $\eta_p^2 = .176$), such that stop-signal delays were shorter for self-owned ($M = 225$ ms, $SD = 59$ ms) compared to other-owned ($M = 236$ ms, $SD = 53$ ms) items.

[3] Data are available at the OSF at the following link: https://osf.io/92yqg/

Failed Inhibition. The only effect to emerge in the analysis was a main effect of Owner (F(1, 57) = 10.88, p = .002, η_p^2 = .160), indicating that inhibition failed more often in response to self-owned (M = 41%, SD = 15%) compared to other-owned (M = 38%, SD = 13%) items.

SSRTs. SSRTs were estimated using the quantile method, which does not rely on the assumption of a 50% inhibition failure rate (Band et al., 2003). To calculate quantile SSRTs, all Go RTs were arranged in ascending order and then the Go RT corresponding to the observed inhibition failure rate was selected, yielding the quantile RT. For example, if the inhibition failure rate were 40%, the .4 quantile from the participant's Go RT distribution would be used. The average SSD was subtracted from this quantile RT, providing an estimate of the SSRT. The analysis yielded main effects of Owner (F(1, 57) = 8.19, p = .003, η_p^2 = .126) and Target of Comparison (F(1, 57) = 5.01, p = .029, η_p^2 = .081). Specifically, SSRTs were shorter for self-owned (M = 323 ms, SD = 64 ms) compared to other-owned (M = 335 ms, SD = 66 ms) items, and response inhibition was more efficient when the target of comparison was a stranger (M = 312 ms, SD = 79 ms) rather than a friend (M = 347 ms, SD = 41 ms, see Figure 1, lower panel).[4]

[4] This effect is interesting as it suggests that response inhibition was easier when the target was not a familiar other.

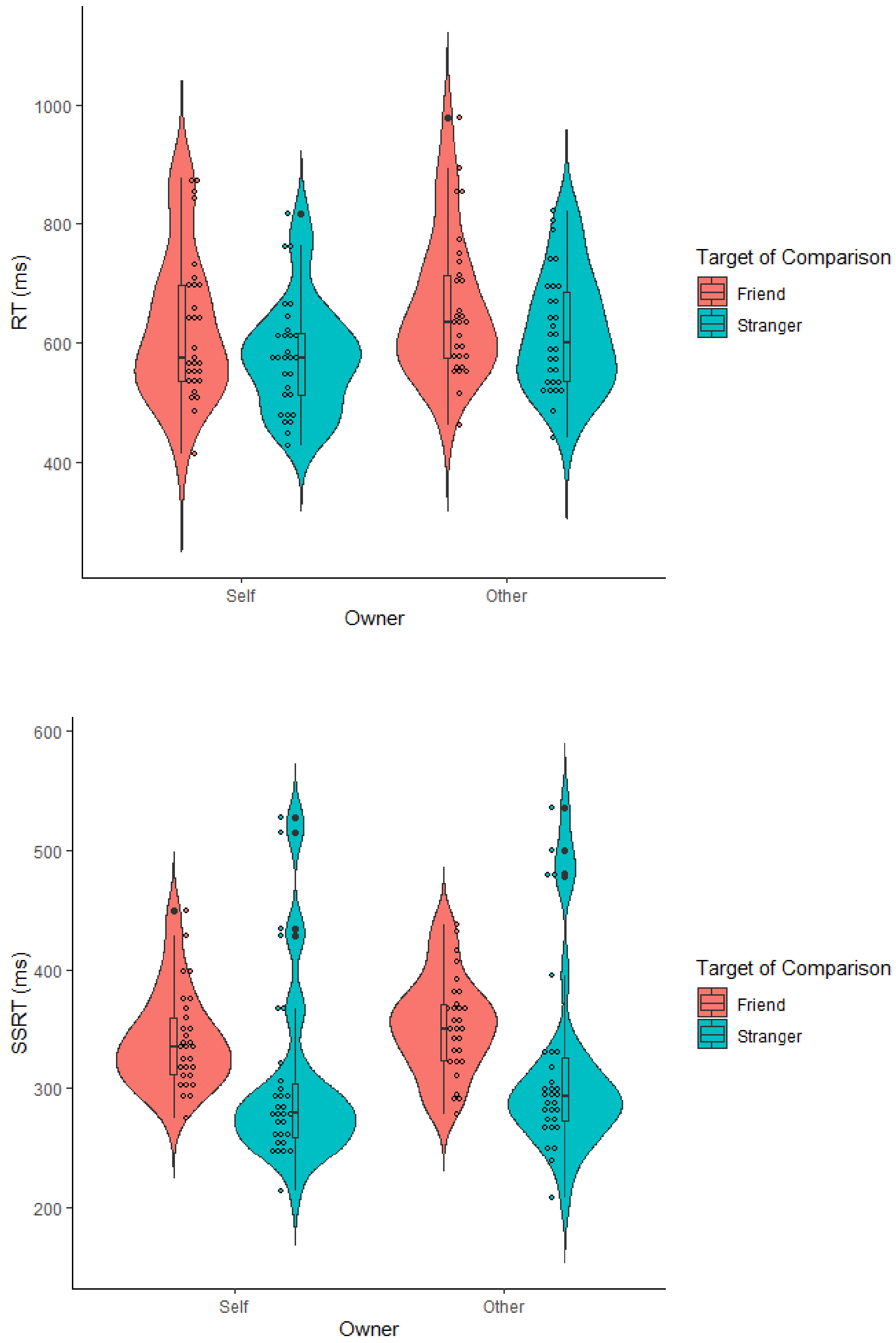

Figure 1. Violin plots depicting the distributions and box plots (within each violin) demonstrating means for Reaction Time (RT, upper panel) and Stop Signal Reaction Time (SSRTs, lower panel) as a function of Owner and Target of Comparison. Each dot represents an individual participant's mean.

Discussion

An extensive literature has revealed the benefits of self-referential processing across a range of domains, most notably memory, attention, and decision-making (Baumeister, 1998; Blakemore & Robbins, 2012; Conway, 2005; Heatherton, 2011; Mezulis et al., 2004; Sheppard et al., 2008). Once paired with the self (vs. other people), stimuli are easier to detect, appraise, and remember (Humphreys & Sui, 2016; Symonds & Johnson, 1997). Extending this line of inquiry, here we demonstrated that the advantages of personal relevance also extend to the efficiency of executive control (Sui & Rotshtein, 2019). Using a stop-signal task, self-relevance was observed to facilitate response inhibition (i.e., shorter SSRTs), whether the target of comparison was a friend or a stranger (Sui et al., 2012). In addition, replicating prior research, response times and accuracy were enhanced for self-owned compared to other-owned objects during Go trials (Falbén et al., 2019, 2020; Golubickis et al., 2018, 2019, in press). These findings support Sui and Rotshtein's (2109) contention that self-relevance influences the attentional operations that underpin executive control (Petersen & Posner, 2012; Posner & Petersen, 1990; Posner et al., 2016).

The overall pattern of observed effects is intriguing. First, according to the horse-race model, shorter Go RTs and SSRTs for self-relevant stimuli suggest that the Stop process must be faster than the Go process (Logan & Cowan, 1984; Logan et al., 1984). In other words, self-relevance yields a stronger influence on executive control than on categorization and visuomotor processing. Stopping an action successfully necessitates the involvement of several cognitive processes — signal detection (i.e., attentional capture by the stop signal), action selection, and action suppression (e.g., not pressing a button; Verbruggen & Logan, 2017). While it is known that the stop signal captures attention automatically, this process can be enhanced if the to-be-judged stimuli are highly relevant (Boehler et al., 2011; Sharp et al., 2010). Given that self-prioritization effects extend to the early components of visual processing (e.g., prior entry, visual awareness, transient attention, Constable et al., 2019; Macrae et al., 2017, 2018; Truong et al., 2017; Yankouskaya, Palmer et al., 2017), it is therefore possible that detection of the stop signal was enhanced by the personal relevance of the stimuli (i.e., self-owned objects), resulting in a faster Stop than Go process.

Second, interesting effects also emerged on the SSDs and rates of failed inhibition. Specifically, participants failed to withhold their responses more frequently during self-owned compared to other-owned trials and, as a result, SSDs were lower. Although these findings are indicative of poorer executive control when responding to self-relevant (vs. other-relevant) stimuli, it may be that the results reflect operations occurring during action selection and suppression. During ownership tasks it has been shown that the evidential requirements of response generation are reduced when judging self-owned (vs. other-owned) objects (Constable et al., 2019; Falbén et al., 2020; Golubickis et al., 2018, 2019). In the context of a stop-signal task, rapid completion of decisional processing and the initiation of a movement (i.e., point of no return) would result in participants failing to withhold some of their responses (hence more failures of inhibition and a lower SSD for self-owned than other-owned objects). These findings suggest that self-relevance influences the processes underlying response inhibition (i.e., signal detection, action selection and suppression) in nuanced and intricate ways.

The current results are consistent with the proposition that ownership impacts visuomotor processing. For example, having given a coffee mug to participants, Constable et al. (2011) demonstrated that compared to an equivalent beaker owned by the experimenter, participants lifted their own mug with greater care and force. Underpinning this effect, they speculated, was a general reluctance on the part of participants to handle other people’s possessions. Interestingly, however, results obtained in an ownership response-compatibility task also suggested that participants either failed to perceive action affordances for other-owned objects or action inhibition may be less efficient when interacting with self-owned items (Constable et al., 2011; Expt. 2). Although picking up other people’s belongings and suppressing pre-potent responses in a stop-signal paradigm tap into quite different facets of inhibition (i.e., difficulty in starting vs. ease of stopping a response), here we demonstrated evidence for a corresponding pattern of results. Specifically, while ownership convincingly biased the primary measures of task performance (e.g., Go RTs & SSRTs), aspects of executive control (i.e., inhibition failures) were impeded by self-relevance. It would be of interest, therefore, to extend the current work to explore when and how this trade-off between task facilitation and impairment emerges (Sui & Rotshtein, 2019).

Although people exert self-control on a daily basis, little is known about the precise manner in which self-relevance moderates response inhibition. In this respect, the Identity-Value Model of self-regulation may provide some valuable clues. According to the model, self-control improves as the goal-directed personal-relevance of behavior increases (Berkman, Hutcherson et al., 2017; Berkman, Livingston et al., 2017). Diverging from the conventional conception (i.e., dual-processing account) that successful regulation is determined by competition between impulsive (i.e., hot) and deliberate (i.e., cold) systems (Evans, 2008; Kahneman, 2011), this framework assumes that self-control is a value-based decision that dynamically integrates subjective values across multiple-choice attributes (Berkman, Hutcherson et al., 2017; Berkman, Livingston et al., 2017). The benefit of treating self-regulation as a decisional process is that it enables well-established phenomena to be harnessed to provide explanations for the effects observed across a range of task contexts. For example, the endowment effect — the tendency to overvalue personal belongings (Kahneman et al., 1991) — has potentially interesting implications for the current findings. As self-owned objects have a larger subjective worth than other-owned items, this will bias decisional processing in favor of the former stimuli, which in turn will facilitate end point outcomes, such as response inhibition (Berkman, Hutcherson et al., 2017; Berkman, Livingston et al., 2017).

What, of course, has yet to be established is the extent to which the current effects extend to other tasks and measures. Executive control consists of several core functions, including inhibition (i.e., response inhibition), interference control (i.e., selective attention), cognitive-flexibility (i.e., creative thinking), and working memory (Diamond, 2013). To widen the scope of the current investigation, future research should explore the extent to which self-relevance influences these other aspects of executive control. Interestingly, Sui and Rotshtein (2019) noted that, depending on the task context, self-relevance could potentially facilitate or impede inhibitory processing. It is probable, therefore, that the linkage between self-relevance and executive control is more complex than the current work suggests. Take, for example, interference control. This component of executive function enables people to selectively focus attention on chosen stimuli while simultaneously suppressing distracting information (e.g., attend to a single voice during a party; Posner & DiGirolamo 1998, Theeuwes, 1991). If, however, self-relevance automatically directs attention (at least temporarily) toward personally meaningful stimuli (Humphreys & Sui, 2016; Sui & Humphreys, 2015), it is possible that interference control may be disrupted in certain settings (Moray, 1959; Röer et al., 2013; Wood & Cowan, 1995). What is needed, therefore, is additional work that informs understanding of when, how, and with what effect self-relevance influences executive control.

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Appendix A. Task performance as a function of Owner and Target of Comparison.

Owner

Target of Comparison	Self	Other
Go RT (ms)		
friend	624 (122)	658 (122)
stranger	577 (95)	617 (99)
Accuracy (%)		
friend	95 (4)	92 (7)
stranger	96 (3)	93 (6)
SSD (ms)		
friend	221 (62)	229 (55)
stranger	229 (56)	243 (50)
Failed inhibition (%)		
friend	39 (16)	37 (13)
stranger	42 (14)	39 (14)
SSRT (ms)		
friend	341 (41)	353 (41)
stranger	306 (77)	317 (80)

Note. RT = reaction time. Standard deviation (*SD*) in parentheses.