



Citation for published version:

Janczyk, M, Glynn W., H & Sui, J 2019, 'The central locus of self-prioritisation', *Quarterly Journal of Experimental Psychology*, vol. 72, no. 5, pp. 1068-1083 . <https://doi.org/10.1177/1747021818778970>

DOI:

[10.1177/1747021818778970](https://doi.org/10.1177/1747021818778970)

Publication date:

2019

Document Version

Peer reviewed version

[Link to publication](#)

Janczyk, M., Humphreys, G. W., & Sui, J. (2019). The central locus of self-prioritisation. *Quarterly Journal of Experimental Psychology*, 72(5), 1068–1083. Copyright © 2018 Experimental Psychology Society. Reprinted by permission of SAGE Publications.

University of Bath

Alternative formats

If you require this document in an alternative format, please contact:
openaccess@bath.ac.uk

General rights

Copyright and moral rights for the publications made accessible in the public portal are retained by the authors and/or other copyright owners and it is a condition of accessing publications that users recognise and abide by the legal requirements associated with these rights.

Take down policy

If you believe that this document breaches copyright please contact us providing details, and we will remove access to the work immediately and investigate your claim.

The central locus of self-prioritization.

Markus Janczyk

Eberhard Karls University of Tübingen, Germany

Glyn W. Humphreys

University of Oxford, UK

Jie Sui

University of Bath, UK

Address correspondence to:

Markus Janczyk
Eberhard Karls University of Tübingen
Department of Psychology
Schleichstraße 4
72076 Tübingen
Germany
Phone: +49 (0)7071 2976761
Email: markus.janczyk@uni-tuebingen.de

Abstract

Self-related information is under many circumstances processed in a preferred and biased way leading to what has been termed the self-prioritization effect (SPE). The SPE has been demonstrated with arbitrary stimuli assigned to self and others thereby for controlling the influence of familiarity (Sui, He, & Humphreys, 2012, JEP:HPP), and originally been attributed to facilitated perceptual processing of self-related stimuli. Subsequent studies, however, casted doubts on this interpretation and suggested further possible sources for the SPE. In the present four experiments, we used the well-established psychological refractory period paradigm together with the locus of slack and the effect propagation logic to pinpoint the source of the SPE. The data consistently demonstrated the SPE across all experiments. More important, the results converge on the notion that the SPE has its source in a capacity-limited stage of central processing. The implications of these results are discussed in light of possible candidate processes as sources for the SPE, such as memory-related processing.

Keywords: self-prioritization ; self-relevance ; PRP ; locus of slack ; effect propagation

Authors' note:

Work of MJ is supported by the Institutional Strategy of the University of Tübingen (German Research Foundation [DFG] ZUK 63). Work of JS is supported by a grant from the Economic and Social Research Council (ES/K013424/1). The authors' wish to remember the important contribution of Glyn W. Humphreys (1954-2016), who has worked on this project from the very beginning.

The central locus of self-prioritization.

Healthy people constantly show biased responses to self-related information compared to information related to others in a wide range of cognitive tasks. This phenomenon is termed the *self-prioritization effect* (SPE). For example, self-related information can attract attention automatically (Gronau, Cohen, & Ben-Shaktar, 2003) and one's own face is responded to faster and more accurately than the faces of other people, no matter whether the face image is displayed upright or upside down (Keenan et al., 1999; Keyes & Brad, 2010). Further, memory tends to be better for items encoded in relation to oneself compared to items encoded in relation to others (Symons & Johnson, 1997). People also tend to associate more positive personality traits with themselves compared with other individuals (Klein, Loftus, & Burton, 1989). However, much of the prior work examining how self-reference affects behavior has used stimuli such as the participant's own face. With such stimuli, however, it is difficult to control the influence of other factors such as differential familiarity. To overcome this limitation, Sui and colleagues developed a perceptual matching task, where people form associations between neutral (equal familiar) stimuli and personal labels (e.g., associating the personal labels you, friend, and stranger with geometrical shapes; Sui, He, & Humphreys, 2012). Following the association instructions, participants may be given simple tasks – for example, to decide whether subsequent shape-label pairs are as originally shown or whether they have been re-paired (e.g., circle-you, triangle-friend, square-stranger), or to classify the neutral shape (self vs. friend) (Sui, Yankouskaya, & Humphreys, 2015). In such experiments, there is an immediate and large advantage for self-related stimuli compared with stimuli related to other people. The SPE in such perceptual matching tasks even maintains through the lifespan (Sui & Humphreys, 2017).

There is rich evidence demonstrating that the SPE as observed in perceptual matching paradigms occurs at different stages and aspects of processing from perception (Sui et al., 2012; Sui et al., 2015), attention (Schäfer, Wentura, & Frings, 2015), memory (Sui & Humphreys, 2013; Reuther & Chakravathi, 2017), outcomes (Fuentes, Sui, Estévez, & Humphreys, 2015), and perhaps even action (Frings & Wentura, 2014). However, even within each of these suggestions there is controversy. For example, in a very recent study, Macrae and colleagues (2017) combined a matching paradigm, in which participants were required to detect the presence/absence of a *specified* shape, with a breaking continuous flash suppression (CFS) approach that renders stimuli invisible. This task was used to assess if self-relevance modulates access to visual awareness. Using a hierarchical drift diffusion model approach that can decompose levels of processing using different parameters (Wiecki, Sofer, & Frank, 2013), they reported that self-relevance enhances visual awareness, and the SPE is associated with both decisional and non-decisional processing. However, a contrary effect with CFS was observed by Stein and colleagues (2016) who also combined the matching paradigm with the CFS approach. It has been argued that the negative result with CFS may reflect a detection task used where participants responded to the presence of stimuli instead of discriminating stimuli (Macrae et al., 2017). Notably, Stein et al. (2016) reported the SPE in the matching task.

Although many studies addressed the source of the SPE, it still lacks a *direct empirical manipulation* to target the locus (or the loci) of the SPE in information processing. To overcome this, we here employed the Psychological Refractory Period (PRP) paradigm that has successfully been used in other many fields (see below, Pashler, 1994; Telford, 1931).

Localizing the source of RT effects with the PRP paradigm. The PRP paradigm has often been used to study effects of dual-tasking and dates back to the work of Telford (1931).

In modern versions of this paradigm, participants perform two tasks on each trial (Task 1 and Task 2, respectively), both of which make use of distinct stimuli (S1 and S2) and require distinct responses (R1 and R2). The time from stimulus onset until the respective response is measured as the response time (RT) in Task 1 and 2 (RT1 and RT2, respectively). The critical manipulation is the time between S1 and S2 onset, the stimulus onset asynchrony (SOA), which is, for example varied between 50 and 1000 ms. While RT1 is often unaffected by this manipulation, RT2 shows a marked increase the smaller the SOA. This *PRP effect* is taken as indicating dual-task interference and only few exceptions exist (see Janczyk, Pfister, Wallmeier, & Kunde, 2014). A still widely accepted account for the PRP effect is the central bottleneck model (Pashler, 1994; Welford, 1952; see Fig. 1a for an illustration). This model assumes that task processing requires a series of (usually three) different stages: The pre-central (perceptual) stage, a central stage, and the post-central (motor) stage. Whatever the exact nature of the central stage is – it most often is related to response selection – the critical assumption is that the cognitive system can at any given moment only handle one such central stage thereby constituting a bottleneck. Hence, if the pre-central stage of Task 2 finishes before the central stage of Task 1 releases the bottleneck, a situation occurring with short but usually not with long SOAs, Task 2 processing must wait. This idle time is called the *cognitive slack*, and produces the longer RT2s at short compared with at long SOAs.

The PRP paradigm has also been used very successfully as a chronometric tool to localize the source of RT effects within the stream of task processing (e.g., Durst & Janczyk, 2018; Janczyk, 2013, 2017; Janczyk, Renas, & Durst, 2017; Miller & Reynold, 2003; Paelecke & Kunde, 2007). Of particular importance for the present purposes are the *locus of slack* logic (Schweickert, 1978) and the *effect propagation* logic (e.g., Miller & Reynolds, 2003; Janczyk et al., 2017; Kunde, Pfister, & Janczyk, 2012). Because the first three

experiments we report here make use of the locus of slack logic, we introduce this approach in the following. The effect propagation logic will be explained in the introduction to Experiment 4.

When using the locus of slack logic, the critical task in which the RT effect of interest is observed (i.e., the SPE in our case) is used as Task 2 in a PRP experiment. Now assume that this manipulation changes the duration of the pre-central, perceptual stage of Task 2. With a long SOA and no idle time of a cognitive slack, this change will affect the onset of the following stages, and thus will produce the investigated RT effect (see Fig. 1b). With short SOAs, however, the change in the duration of pre-central processing does not become visible because the Task 2 response selection can only start after Task 1 response selection has finished. Even if a manipulation lengthens the duration of pre-central processing, this additional time simply stretches into the cognitive slack, and does not further delay the onset of subsequent stages. Thus, the RT effect resulting from the manipulation of interest will not be observable in RT2 with a short SOA. Statistically, this results in an (underadditive) interaction of SOA and the manipulation of interest. In contrast, if the manipulation affects the central (or post-central) stage, the RT effect will be visible in RT2 across all SOA conditions, and combine additively with the SOA (see Fig. 1c).

**** Figure 1 about here ****

The present study. As mentioned above, the SPE may have several sources within the stream of processing from stimulus perception to motor execution of the corresponding response. The present experiments aimed at pinpointing the source of the SPE by using the PRP paradigm as a chronometric tool.

Is there evidence favoring a pre-central perceptual locus of the SPE, perhaps suggesting that that self-related information is perceptually encoded faster than is other information? In fact, this possibility appears viable when considering the results of Experiment 4 by Sui et al. (2012), which used the additive factors logic (Sternberg, 1969). Following this logic, two manipulations affect RTs in an additive way if they both target different stages of processing. In contrast, if both manipulations target the same stage, they should interact with each other. One acknowledged way to affect early perceptual processes is, for example, manipulating stimulus luminance. Thus, if the SPE also has a source in the perceptual stage, it should interact with a brightness manipulation. It turned out in Experiment 4 of Sui et al. that the manipulation of stimulus luminance indeed interacted significantly with the SPE, suggesting that the manipulation of visual luminance and the SPE both affect the same stage of processing, most likely the stage of perceptual processing. In turn, manipulations affecting perceptual processing have in fact produced underadditive interactions in PRP experiments (Paelecke & Kunde, 2007; Pashler & Johnston, 1989), and so should the SPE do as well if resulting from a perceptual facilitation of self-related stimuli. In addition, if self-reference acts on the level of perceptual binding similar to processes occurring in visual conjunction search tasks, an underadditive interaction appears likely as it was previously reported with such tasks (Reimer, Strobach, Frensch, & Schubert, 2015; Reimer, Strobach, & Schubert, 2016; but see also Brisson & Jolicoeur, 2007). Apart from early perceptual manipulations, retrieval from semantic and episodic memory was shown to happen in parallel with other processes (Logan & Delheimer, 2001; Logan & Schulkind, 2000). Thus, if the SPE results from faster retrieval of semantic or episodic memory traces, an underadditive interaction may result as well.¹

¹ It is also worth noting that some non-perceptual manipulations yielded underadditive interactions with SOA as well, for example, the picture-word interference task (Dell'Acqua, Job, Peressotti, & Pascali, 2007). In this task,

In contrast, there are several results in the existing literature making a central locus of the SPE more likely. A study by Macrae et al. (2017) suggests the SPE to not result from differences in perceptual uptake, as indicated by an analysis of drift rates within the diffusion modelling framework. Further, encoding into short-term memory (Jolicoeur & Dell'Acqua, 1998) and switching between working memory items (Janczyk, 2017) were shown to be capacity-limited and requiring the central bottleneck. Thus, if the SPE indexes easier encoding or selection of self-related items into or within working memory, an additive combination of the SPE with SOA would be predicted. Also, “higher level perceptual processing (such as stimulus classification)” (Johnston & McCann, 2006, p. 699) was shown to require the central bottleneck. Further, Garner interference (e.g., Garner, 1978), that is, the negative impact of task-irrelevant stimulus variations on judging the task-relevant dimension combined additively with the SOA (Janczyk, Franz, & Kunde, 2010; Janczyk & Kunde, 2010). Thus, although at first sight a perceptual phenomenon, empirical work highlights an implication of the capacity-limited central stage to the resolution of Garner interference.

It is also possible that the SPE has its source in two different stages (Sui & Humphreys, 2015). For example, an ERP study by Liu, He, Rotshtein, and Sui (2016) showed that self-relevance modulates both attention selection and decision making. If the SPE indeed affects both the pre-central stage and the capacity-limited central stage, however, the central bottleneck model still predicts an underadditive interaction, with the SPE itself still being significant at the short SOA, instead of being completely absorbed into the slack. Such RT

a line drawing is presented on-screen and to be named by the participants. Critically, the picture is accompanied by a distractor word which is either conceptually related or not to the picture. Such work highlights that, in principle, non-perceptual manipulations may also yield underadditive interactions with SOA.

patterns have been reported before by Janczyk (2013) and Klapötke, Krüger, and Mattler (2011).²

Experiments 1-3 were run to distinguish between these alternative views about where in the stream of processing the SPE emerges. A possible motor component to the SPE will then be discussed in the introduction to Experiment 4.

Experiments 1a and 1b

In these experiments, each trial comprised two stimuli. S1 was a tone and S2 was a geometric shape combined with a word. In Task 2, participants were to judge whether the particular combination matched a previously learned association. In general, Task 2 was modelled following Experiment 1 of Sui et al. (2012). Both experiments differed only slightly with regards to timing parameters which were changed after participants in Experiment 1a reported difficulties in performing Task 1 as fast as possible due to the short S2 presentation time.

Method

Participants. Twenty-four³ students from University of Würzburg participated in each of these experiments in exchange for course credit (Exp. 1a: mean age = 26.0 years, 22 females; Exp. 1b: mean age = 26.2 years, 16 females). Participants had normal or corrected-

² Note that a similar result would be obtained if a manipulation lengthens the duration of a pre-central processing stage more than the cognitive slack time is. In this case, an increase in Task 1 response selection difficulty could be used to increase the slack time, for example, using more than two stimuli and responses in Task 1.

³ To allow for a better interpretation of the results, we ran a post-hoc power calculation. Because the analyses involve 2×3 and 2×2 within-subjects Analyses of Variance, we used an effect-size correction method (Rasch, Friese, Hofmann, & Naumann, 2010) that allows one to use G*Power (Faul, Erdfelder, Lang, & Buchner, 2007) in these cases. To achieve a power of $1-\beta = .8$ while assuming $\alpha = .05$, $\rho = .3$, and a medium effect-size of $f = .25$, the required sample sizes to detect a significant interaction were $n = 20$ for the 2×3 interaction in Experiments 1a, 1b, 2, and 4, and $n = 24$ for the 2×2 interaction in Experiment 3.

to-normal vision and reported no hearing difficulties. They were also naïve regarding the purpose of the experiment and signed informed consent prior to the experiment.

Apparatus and stimuli. Experimental procedures were controlled by a standard PC. S1 were 300 and 900 Hz tones (50 ms) presented via headphones. Task 2 visual stimuli were presented in white against a black background. The shapes were a triangle, a square, and a circle; the associated words were “Du”, “Freund”, and “Fremder” (“You”, “Friend”, and “Stranger”, respectively). Responses were given via custom-built external response keys, two located to each side of the participants.

Procedure and tasks. The experiment had two stages. In the training stage, participants were asked to encode verbally-labeled geometric shapes as the self, a named best friend, and a stranger. None of the shapes were actually shown at this stage, but participants were informed in written form on the computer screen (for 60 seconds). After this, the PRP experiment proper started. On each trial, participants worked on two tasks: An auditory discrimination task (Task 1) and the matching task (Task 2). Following a fixation cross (500 ms) S1 was played. The respective response R1 was given with the left index-/middle-finger. Following an SOA of 50 or 1000 ms (Exp. 1a) or of 100 or 1000 ms (Exp. 1b), S2 was presented for 100 ms (Exp. 1a) or 300 ms (Exp. 1b) consisting of a geometric shape plus a word denoting one of the three categories (to which the shapes were associated previously). Both shape and label were horizontally centered with the shape located slightly above the screen center and the label below the shape. Participants’ task was to indicate whether or not the given combination matched with the associations learned in the training stage. The respective response R2 was given with the right middle-/index-finger. A trial was cancelled when both responses were not given within 2500 ms after S2 onset. In case of erroneous responses, error feedback was given after the responses (specific to the tasks or indicating

general errors such no response within 2500 ms after S2 onset or R2 given before R1); participants were informed about their overall accuracy after each block. Each block consisted of 72 trials, resulting from three repetitions of 2 (S1: 300 vs. 900 Hz) \times 2 (SOA: 50/100 vs. 1000 ms) \times 3 (shape: triangle, square, circle) \times 2 (match: match vs. nonmatch) = 24 trial types, presented in random order (for nonmatch trials, both possible labels occurred equally often). Participants received written instructions, emphasizing speed, accuracy, and prioritizing Task 1 over Task 2. Then, the experiment started with a brief familiarization block of 10 randomly drawn trials, followed by six complete blocks. The first of these blocks was considered practice and not analyzed. S-R mappings in Task 1 (2) and shape-category mappings (6) were counterbalanced across participants. The full experimental design is three-factorial with SOA (50/100 vs. 1000), shape category (self vs. friend vs. stranger), and match (match vs. nonmatch) as repeated-measures.

The experimental session for Experiment 1a took about 75 minutes. A first unrelated experiment (a pilot study in the context of idemotor theory) was followed by a break of about 10 minutes. Then, Experiment 1a was started and took about 45 minutes. Experiment 1b was tested in one single session of 45 minutes. All participants were tested individually in a small experimental room.

Design and analyses.

Trials with general errors (no response within 2500 ms after S2 onset, R2 given prior to R1, ...) were excluded for all analyses. RT analyses were based on entirely correct trials only. Outliers were identified as RTs deviating by more than 3 *SDs* from the corresponding mean (calculated separately for each participant and design cell). As the most interesting

condition concerns the RTs when shape category and the word match⁴, separate 2×3 ANOVAs for match and nonmatch trials with SOA and shape as repeated measures are reported for RTs, regardless of whether the three-way interaction of the full design is significant or not. However, detailed inferential statistics of the full three-way ANOVA on RTs with match as an additional repeated measure are summarized in the Appendix in Tables A1 and A2. In case of violations of the sphericity assumption, Greenhouse-Geisser corrections were applied, and we report uncorrected degrees of freedom accompanied by the respective ϵ -estimate. Because the critical result concerns a non-significant interaction of SOA and shape (which excludes a perceptual locus of the SPE), we also report the BF_{01} and the $p_{BIC}(H_0|Data)$ according to Wagenmakers (2007) and Masson (2011) for these interactions. For Task 2 RTs, we followed up these analyses with Tukey contrasts for pairwise comparisons of the three shapes, collapsed across SOA levels (using the `glht()` function of the R-package `multcomp`).

Results

As the theoretically more interesting results relate to Task 2, these are reported first followed by the Task 1 results.

Experiment 1a: Task 2. Mean correct RT2s (1.24% outliers) are visualized in Figure 2 (upper panels; see also Table 1) separately for matching and nonmatching trials. The three-way interaction approached significance, $F(2, 46) = 2.69, p = .079, \eta_p^2 = .10$. In *match trials*, RT2s were longer with the short SOA (1353 ms) than with the long SOA (731 ms), thus a PRP effect, $F(1, 23) = 528.63, p < .001, \eta_p^2 = .96$. Shape category had a significant effect with

⁴ This focus followed previous studies (Sui et al., 2012; Sun et al., 2016) because it is difficult to distinguish the contributions of self- and other-related information to the SPE in nonmatch trials (which also include self-related information).

RT2s being shorter to self-related stimuli (941 ms), intermediate to friend-related stimuli (1065 ms), and longest to stranger-related stimuli (1119 ms), $F(2, 46) = 31.64, p < .001, \eta_p^2 = .58$. The interaction was not significant, that is, both factors combined additively, $F(2, 46) = 0.78, p = .463, \eta_p^2 = .03, BF_{01} = 16.07, p_{BIC}(H_0|D) = .941$. Across SOAs, the differences between self-stranger and self-friend were significant, $p < .001$, while the difference friend-stranger was not, $p = .072$. A similar pattern was observed in *nonmatch trials*. RT2s were longer with a short SOA (1518 ms) than with a long SOA (820ms), $F(1, 23) = 670.71, p < .001, \eta_p^2 = .97$. Responses were again faster to self-related stimuli (1099 ms), but intermediate to stranger-related stimuli (1177 ms), and slowest to friend-related stimuli (1209 ms), $F(2, 46) = 14.90, p < .001, \eta_p^2 = .39$. The interaction was not significant, $F(2, 46) = 1.23, p = .296, \eta_p^2 = .05, \varepsilon = .80, BF_{01} = 12.84, p_{BIC}(H_0|D) = .928$. Across SOAs, the differences self-friend, $p < .001$, and self-stranger, $p = .001$, were significant, while the difference friend-stranger was not, $p = .319$.

Mean percentages error (PEs) in Task 2 (thus PE2s) are summarized in Table 1 and do not contradict the RT2 pattern. Overall, less errors occurred with a long than with a short SOA, $F(1, 23) = 4.43, p = .046, \eta_p^2 = .16$. Further, the main effect of shape category was significant, $F(2, 46) = 11.18, p < .001, \eta_p^2 = .33$: Participants committed the least errors in self-related trials. However, similar as for RTs, for match trials most errors were committed in stranger-related trials, but for nonmatch trials in friend-related trials, supported by the significant interaction shape category \times match, $F(2, 46) = 6.44, p = .003, \eta_p^2 = .22$. All other $F_s \leq 0.75$, all $p_s \geq .479$.

Experiment 1a: Task 1. Mean RT1s (1.28% outliers) are summarized in Table 1. The three-way interaction approached significance, $F(2, 46) = 2.73, p = .076, \eta_p^2 = .11$. In *match trials*, RT1s were shorter with a long SOA (915 ms) than with a short SOA (1107 ms), $F(1,$

23) = 20.54, $p < .001$, $\eta_p^2 = .47$. Also, overall RT1s were shorter in self-related trials (979 ms), intermediate in friend-related trials (1016 ms), and longest in stranger-related trials (1040 ms), $F(2, 46) = 7.62$, $p = .001$, $\eta_p^2 = .25$. This latter pattern was more pronounced at the short SOA and accordingly the interaction was significant, $F(2, 46) = 3.34$, $p = .044$, $\eta_p^2 = .13$. In *nonmatch trials*, RT1s also were shorter at the long SOA (922 ms) compared to the short SOA (1216 ms), $F(1, 23) = 43.72$, $p < .001$, $\eta_p^2 = .66$. However, there was no significant effect of shape category, $F(2, 46) = 2.50$, $p = .105$, $\eta_p^2 = .10$, $\epsilon = .81$, and the interaction was also not significant, $F(2, 46) = 2.60$, $p = .085$, $\eta_p^2 = .10$.

Mean PE1s are summarized in Table 1. There was only a significant main effect of SOA indicating less errors with a long SOA than with a short SOA, $F(1, 23) = 17.87$, $p < .001$, $\eta_p^2 = .44$. All other $F_s \leq 2.16$, all $p_s \geq .127$.

**** Figure 2 about here ****

**** Table 1 about here ****

Experiment 1b: Task 2. Mean correct RT2s (1.13% outliers) are visualized in Figure 2 (lower panels; see also Table 2) separately for matching and nonmatching trials. The three-way interaction was not significant, $F(2, 46) = 0.14$, $p = .825$, $\epsilon = .80$, $\eta_p^2 = .10$. In *match trials*, RT2s were shorter with a long SOA (771 ms) than with a short SOA (1341ms), thus a PRP effect, $F(1, 23) = 294.24$, $p < .001$, $\eta_p^2 = .93$. RT2s were also shorter in self-related trials (958 ms), and comparable in friend-related (1107 ms) and stranger-related trials (1103 ms), $F(2, 46) = 23.08$, $p < .001$, $\eta_p^2 = .50$. Importantly, the interaction was far from significance, $F(2, 46) = 0.33$, $p = .718$, $\eta_p^2 = .01$, $BF_{01} = 20.19$, $p_{BIC}(H_0|D) = .953$. Across SOAs, the differences between self-stranger and self-friend were significant, $p < .001$, while the difference friend-stranger was not, $p = .987$. Similar results were observed in *nonmatch trials*.

A clear PRP effect was evident with shorter RT2s with the long SOA (875 ms) than with the short SOA (1453 ms), $F(1, 23) = 283.52, p < .001, \eta_p^2 = .92$. Further, RT2s were shortest in self-related trials (1104 ms), intermediate in stranger-related trials (1152 ms), and longest in friend-related trials (1216 ms), $F(2, 46) = 17.19, p < .001, \eta_p^2 = .43$. The interaction was not significant, $F(2, 46) = 0.80, p = .425, \eta_p^2 = .03, \epsilon = .76, BF_{01} = 15.90, p_{BIC}(H_0|D) = .941$. Across SOAs, the differences between self-friend, $p < .001$, and friend-stranger, $p = .008$, were significant, while the difference self-stranger just missed significance, $p = .051$.

Mean PE2s are summarized in Table 2. Fewer errors were committed at the long compared to the short SOA, but the main effect of SOA just missed significance, $F(1, 23) = 3.71, p = .067, \eta_p^2 = .14$. There were also slightly more errors in the nonmatch trials, but the main effect also just missed significance, $F(1, 23) = 4.05, p = .056, \eta_p^2 = .15$. The shape category effect, however, was significant, $F(2, 46) = 4.42, p = .018, \eta_p^2 = .16$, but modified by a significant shape category \times match interaction, $F(2, 46) = 16.27, p < .001, \eta_p^2 = .41, \epsilon = .80$. While in match trials the least errors were made in self-related trials, PEs in self-related trials lay in between stranger- and friend-related nonmatch trials. All other $F_s \leq 1.55$, all $p_s \geq .225$.

Experiment 1b: Task 1. Mean correct RT1s (1.08% outlier) are summarized in Table 2. The three-way interaction was not significant, $F(2, 46) = 2.52, p = .092, \eta_p^2 = .10$. In *match trials*, RT1s were shorter with a long SOA (858 ms) than with a short SOA (1073 ms), $F(1, 23) = 29.14, p < .001, \eta_p^2 = .56$, and overall shortest in self-related trials (936 ms), intermediate in stranger-related trials (966 ms), and longest in friend-related trials (993 ms), $F(2, 46) = 7.17, p = .002, \eta_p^2 = .24$. The differences between the shape categories were more pronounced at the short SOA, $F(2, 46) = 4.64, p = .015, \eta_p^2 = .17$, for the interaction. In *nonmatch trials*, RT1s were also shorter at the long SOA (858 ms) compared with the short SOA (1099 ms), $F(1, 23) = 33.93, p < .001, \eta_p^2 = .60$, but they did not differ depending on S2

shape category, $F(2, 46) = 1.96, p = .166, \eta_p^2 = .08, \varepsilon = .74$. The interaction was far from significance, $F(2, 46) = 0.04, p = .924, \eta_p^2 < .01, \varepsilon = .76$.

Mean PE1s are summarized in Table 2. Less errors were made with the long SOA, $F(1, 23) = 9.37, p = .006, \eta_p^2 = .29$. All other F s ≤ 1.65 , all p s $\geq .211$.

**** Figure 3 about here ****

**** Table 2 about here ****

Discussion.

The results obtained with Task 2 match-trials replicate the single-task results reported by Sui et al. (2012, Exp. 1). Most importantly, responses were clearly fastest in self-related trials, that is, the SPE. This was also the case for nonmatch trials. Critically, the interactions with SOA were not significant. According to the locus of slack logic, this result excludes a pre-central perceptual locus of the SPE. Unexpectedly we also observed effects of the manipulations on Task 1 performance. Most notably, Task 1 RTs were shorter with the long in comparison with the short SOA, but the central bottleneck model does not predict any effect on Task 1 performance. Because we will observe similar results in the following experiments, we will come back to this observation in the General Discussion.

Experiment 2

The results from the previous experiments are not in line with a precentral, perceptual locus of the SPE. One point worth considering is that the SPE in the matching task reflects the personal label-shape associations which participants have to form to be able to access the established knowledge associated with the self. This in itself might require central resources and the additive pattern pointing to a central locus of the SPE may not be surprising. To test

this possibility, in Experiment 2 the personal label (word) was presented 100 ms before the geometrical shape in a sequential version of the matching task. We reasoned that there could be top-down facilitation from having assessed the associated knowledge via the personal label and subsequently lead to easier perceptual processing of the shape. This manipulation may increase the likelihood to observe an underadditive interaction.

Method.

A new sample of 24 participants was recruited following the specifications of Experiment 1 (mean age = 20.6 years, 21 females). Experiment 2 was the same as Experiment 1b with one modification: The word part of S2 was presented 100 ms before the geometrical shape to give its processing a headstart. As a consequence, with the SOA = 100 ms condition, the word appeared simultaneously with the S1 tone. Detailed inferential statistics of the full three-way ANOVA on RTs are summarized in the Appendix in Table A3.

Results.

Task 2. Mean correct RT2s (1.31% outliers) are visualized in Figure 3 (see also Table 3) separately for matching and nonmatching trials. The three-way interaction was not significant, $F(2, 46) = 0.51, p = .602, \eta_p^2 = .03$. In *match trials*, RT2s were longer with a short SOA (1409 ms) compared with a long SOA (784 ms), that is, a PRP effect, $F(1, 23) = 586.51, p < .001, \eta_p^2 = .96$. RT2s were also shortest in self-related trials (988 ms), intermediate in friend-related trials (1129ms), and longest in stranger-related trials (1179 ms), $F(2, 46) = 22.87, p < .001, \eta_p^2 = .50$. Importantly, the interaction was far from significance, $F(2, 46) = 0.08, p = .926, \eta_p^2 < .01, BF_{01} = 23.05, p_{BIC}(H_0|D) = .958$. Across SOAs, the differences between self-stranger and self-friend were significant, $p < .001$, while the difference friend-stranger was not, $p = .179$. Comparable results were observed in *nonmatch trials*. A clear PRP

effect was evident with longer RT2s at the short SOA (1555 ms) than at the long SOA (866 ms), $F(1, 23) = 529.14, p < .001, \eta_p^2 = .96$, and RT2s were shortest in self-related trials (1125 ms), but almost identical for friend-related (1247 ms) and stranger-related trials (1251 ms), $F(2, 46) = 26.13, p < .001, \eta_p^2 = .53$. The interaction was again not significant, $F(2, 46) = 0.43, p = .654, \eta_p^2 = .02, BF_{01} = 19.24, p_{BIC}(H_0|D) = .951$. Across SOAs, the differences between self-stranger and self-friend were significant, $p < .001$, while the difference friend-stranger was not, $p = .972$.

Mean PE2s are summarized in Table 3. PE2s increased from self-related over friend-related to stranger-related trials, thus a main effect of shape category, $F(2, 46) = 8.15, p = .001, \eta_p^2 = .26$. However, this main effect was modified by a significant shape category \times match interaction, $F(2, 46) = 7.41, p = .002, \eta_p^2 = .24$: The shape category effect was much more pronounced in match than in nonmatch trials. All other $F_s \leq 2.49$, all $p_s \geq .094$.

Task 1. Mean RT1s (1.24% outlier) are summarized in Table 3. The three-way interaction was not significant, $F(2, 46) = 0.88, p = .421, \eta_p^2 = .04$. In *match trials*, RT1s were comparable at the short SOA (1116 ms) and at the long SOA (1096 ms), $F(1, 23) = 0.17, p = .685, \eta_p^2 = .01$. They were shortest in self-related trials (1077 ms) and comparable in friend-related (1121 ms) and stranger-related trials (1125 ms), $F(2, 46) = 3.52, p = .038, \eta_p^2 = .13$. The interaction was not significant, $F(2, 46) = 0.64, p = .532, \eta_p^2 = .03$. In *nonmatch trials*, RT1s were slightly shorter at the long SOA (1096 ms) compared to the short SOA (1201 ms), $F(1, 23) = 3.70, p = .067, \eta_p^2 = .14$. The main effect of shape category was not significant, $F(2, 46) = 2.00, p = .163, \eta_p^2 = .08, \epsilon = .69$, and neither was the interaction, $F(2, 46) = 1.94, p = .155, \eta_p^2 = .08$.

Mean PEIs are summarized in Table 3. Less errors were made with the long SOA, $F(1, 23) = 32.69, p < .001, \eta_p^2 = .59$, and slightly more errors were made in the nonmatch condition, $F(1, 23) = 6.21, p = .020, \eta_p^2 = .21$. All other F s ≤ 2.06 , all p s $\geq .139$.

**** Figure 3 about here ****

**** Table 3 about here ****

Discussion.

In Experiment 3 we gave the word-part of S2 a headstart to give participants a chance to assess the associated knowledge before the geometrical shape occurred. Despite this change, the results replicate those from Experiments 1a and 1b. The SPE was observed, but it again combined additively with the SOA manipulation. Thus, the results argue once again against a pre-central perceptual locus of the SPE. Note that again the Task 1 RTs were descriptively shorter with a long than with a short SOA, although this effect was not significant in this experiment.

Experiment 3

Experiments 1-2 tested self-prioritization using a matching task, and no evidence for a pre-central perceptual source for the SPE was observed so far. To complement and generalize this picture, we replaced the matching task with a shape identification task in Experiment 3 (see also Sui et al., 2015).

Method.

A new sample of 24 participants from the University of Tübingen was recruited following the specifications of Experiment 1 (mean age = 21.3 years, 21 females).

Task 1 was as in the previous experiments. Task 2 used four different geometrical shapes (triangle, circle, diamond, and square). Two of these shapes were randomly (for each participant) assigned to an “I”-response, the other two were assigned to a “stranger”-response. Following the tone as S1 and an SOA of 50 or 1000 ms, either one or two geometrical figures were presented centrally (and next to each other in case of two objects). Participants were to respond with the assigned response key in case the single or both shapes were of the “I” or “stranger” type. If two shapes occurred, but both were of different response categories, no response in Task 2 was required (catch trials). These catch trials were introduced to make participants more attentive to the stimuli and task. This helps to maximize the effect size, because previous studies have shown that the SPE in perceptual matching is smaller when the experiments used shapes alone than when they used shape-label pairings (Sui et al., 2015).

Each block comprised 32 trials with two shapes of the same response category (16 for each category), 24 trials with only one shape (12 for each category), and 12 catch trials, that is 68 trials in total. S1 and SOAs were equally often combined with each possible S2. Participants started with ten randomly drawn familiarization trials, which were followed by one (unanalyzed) practice block and five experimental blocks. RTs and PEs were submitted to a 2×2 ANOVA with repeated measures on SOA and shape category.

Results.

Task 2. Mean correct RT2s (1.57% outliers) are visualized in Figure 4 and are summarized in Table 4. Responses were slower with a short SOA (1274 ms) compared to with a long SOA (685 ms), thus a PRP effect, $F(1, 23) = 795.71, p < .001, \eta_p^2 = .97$. Second, responses were faster to self-related stimuli (956 ms) than to stranger-related stimuli (1004 ms), that is, an SPE, $F(1, 23) = 6.96, p = .015, \eta_p^2 = .23$. Importantly, the interaction was not significant, $F(1, 23) = 0.53, p = .475, \eta_p^2 = .02, BF_{01} = 3.73, p_{BIC}(H_0|D) = .789$.

Mean PE2s are summarized in Table 4, and no effect approached significance, all F s \leq 0.86, all p s \geq .362.

Task 1. Mean correct RT1s (1.36% outliers) are summarized in Table 4. Responses were faster with the long SOA (891 ms) compared to the short SOA (966 ms), but the main effect of SOA just missed significance, $F(1, 23) = 3.98, p = .058, \eta_p^2 = .15$. The main effect of category was not significant, $F(1, 23) < 0.01, p = .956, \eta_p^2 < .01$, and neither was the interaction shape category \times SOA, $F(1, 23) = 0.57, p = .459, \eta_p^2 = .02$.

Mean PE1s are summarized in Table 4. More errors occurred at the short compared to the long SOA, $F(1, 23) = 7.61, p = .011, \eta_p^2 = .25$. No other effect reached significance, all F s \leq 1.56, all p s \geq .224.

**** Figure 4 about here ****

**** Table 4 about here ****

Discussion.

Experiment 3 used an identification task instead of the matching task that was used in the previous experiments. First, an SPE was again observed with this task in a dual-task setting. Second, and more importantly, this effect combined again additively with SOA. Hence, again no evidence for a pre-central perceptual source of the SPE was observed. Third, however, Task 1 RTs were once again descriptively shorter with the long than with the short SOA, although this effect just missed significance.

Experiment 4

The results from the previous experiments exclude the pre-central perceptual stage as the source of the SPE. However, to be precise, the locus of slack logic, which was used in these

experiments, does not allow to distinguish whether the resulting additive pattern of the SOA and the SPE has its origin in the central bottleneck stage or in the subsequent stage of motor execution. To the best of our knowledge, there is no study showing clear evidence in favor of a self-biased execution of movements. The most related study is perhaps the one by Frings and Wentura (2014) who used action-label associations in their experiments and observed shorter RTs and higher d' -values in their action-label matching task. However, while suggesting that an action plan may be preferentially accessed or matched with self-related stimuli, thus being in line with a general SPE, these results did not show that the execution of the movement itself was affected by self-related stimuli.

To test whether the motor stage contributes to the SPE within the same paradigm as used in the previous experiments, one can use the effect propagation logic (Janczyk et al., 2017; Miller & Reynolds, 2002; Kunde et al., 2012), which is illustrated in Figure 5. To make use of this approach, the task order from a locus of slack experiment is typically simply reversed, that is, Task 2 becomes Task 1 and vice versa. As a consequence, the critical manipulation – in our case the SPE – is now implemented in Task 1. Then the following two predictions can be derived for the short SOA: If the SPE has its origin in the post-central motor stage, this should not affect processing of the unrelated Task 2, since the motor stage is assumed to run in parallel with other stages (see Fig. 5a). In contrast, if the source of the SPE is prior to the motor stage, this should delay the beginning of the capacity-limited central stage in Task 2 and thus the same effect as in Task 1 should become visible in RT2s (see Fig. 5b). Note that for longer SOAs, no or at least less Task 1 effect propagation into Task 2 is expected (see Fig. 5c). Thus, ideally an overadditive combination of the (propagated) effect with SOA is expected for RT2s in case the Task 1 effect has its source prior to the motor stage.

Method.

A new sample of 24 undergraduate students from the University of Tübingen was recruited, otherwise following the specifications of Experiment 1 (mean age = 21.0 years, 17 females).

Experiment 4 was in many aspects similar to Experiment 1a with one major difference: Task order was reversed, that is, the stimulus for the category matching task (the word-part plus the geometrical shape) occurred first on screen (now S1), and after an SOA of 50 or 1000 ms, the auditory stimuli was played (now S2). Analyses were also comparable, but we report Task 1 results first, because it is a pre-requisite for the further analyses to observe the SPE in Task 1 now. Given that this effect is observed, the most important analyses for effect propagation are comparisons of mean differences between Task 1 and Task 2 RTs at the short SOA. We focused this comparison on match trials, and tested the differences for (1) self- and friend-related trials and (2) self- and stranger-related trials. Detailed inferential statistics on the full ANOVA are provided in the Appendix in Table A4.

Results.

Task 1. Mean correct RT1s (1.22% outliers) are visualized in Figure 6 separately for match and nonmatch trials (see also Table 5). The three-way interaction was not significant, $F(2, 46) = 0.38, p = .686, \eta_p^2 = .02$. In *match trials*, RT1s were shorter with a long SOA (946 ms) than with a short SOA (1003 ms), $F(1, 23) = 8.42, p = .008, \eta_p^2 = .27$. They were also shorter for self-related trials (855 ms), intermediate for friend-related trials (1026 ms), and longest for stranger-related trials (1046 ms), $F(2, 46) = 19.33, p < .001, \eta_p^2 = .46$. The interaction was far from significance, $F(2, 46) = 0.29, p = .751, \eta_p^2 = .01, BF_{01} = 20.68, p_{BIC}(H_0|D) = .954$. Across SOAs, the differences between self-stranger and self-friend were

significant, $p < .001$, while the difference friend-stranger was not, $p = .823$. In *nonmatch trials*, RT1s were also shorter with a long SOA (1080 ms) than with a short SOA (1167 ms), $F(1, 23) = 26.68$, $p < .001$, $\eta_p^2 = .54$. They were also shorter for self-related trials (1009 ms), but intermediate for stranger-related trials (1154 ms), and longest for friend-related trials (1218 ms), $F(2, 46) = 26.57$, $p < .001$, $\eta_p^2 = .54$. The interaction was far from significance, $F(2, 46) = 0.18$, $p = .833$, $\eta_p^2 = .01$, $BF_{01} = 21.81$, $p_{BIC}(H_0|D) = .956$. Across SOAs, the differences between self-stranger and self-friend were significant, $p < .001$, while the difference friend-stranger was not, $p = .080$.

Mean PE1s are summarized in Table 5. There was a main effect of shape category, $F(2, 46) = 4.33$, $p = .019$, $\eta_p^2 = .16$, which was qualified by a significant interaction of shape category \times match, $F(2, 46) = 4.32$, $p = .034$, $\eta_p^2 = .16$, $\varepsilon = .70$: In nonmatch trials, least errors were committed in self-related trials, more errors occurred in stranger-related trials, and most errors occurred in friend-related trials. In match trials, about the same amount of errors occurred in self- and friend-related trials, and more errors occurred in stranger-related trials. All other $F_s \leq 1.75$, all other $p_s \geq .198$.

Task 2. Mean correct RT2s (1.45% outliers) are visualized in Figure 6 separately for match and nonmatch trials (see also Table 5). The three-way interaction was not significant, $F(2, 46) = 0.51$, $p = .603$, $\eta_p^2 = .02$. In *match trials*, RT2s were shorter with a long SOA (721 ms) than with a short SOA (1329 ms), that is, a PRP effect, $F(1, 23) = 1119.27$, $p < .001$, $\eta_p^2 = .98$. They were also shortest for self-related trials (950 ms), intermediate for friend-related trials (1060 ms), and longest for stranger-related trials (1068 ms), $F(2, 46) = 14.08$, $p < .001$, $\eta_p^2 = .38$, $\varepsilon = .77$. This latter effect was more pronounced at the short SOA compared with the long SOA, thus an overadditive interaction, $F(2, 46) = 6.15$, $p = .004$, $\eta_p^2 = .21$. In *nonmatch trials*, RT2s were also shorter with a long SOA (773 ms) compared with a short SOA (1522

ms), $F(1, 23) = 1207.23, p < .001, \eta_p^2 = .98$. They were also shortest for self-related trials (1070 ms), but intermediate for stranger-related trials (1165 ms), and slowest for friend-related trials (1205 ms), $F(2, 46) = 21.75, p < .001, \eta_p^2 = .49$. This latter effect was more pronounced at the short SOA, resulting in an overadditive interaction, $F(2, 46) = 10.68, p < .001, \eta_p^2 = .32$.

Mean PE2s are summarized in Table 5. Participants made more errors at the short compared to the long SOA, $F(1, 23) = 5.84, p = .024, \eta_p^2 = .20$, and in nonmatch compared to match trials, $F(1, 23) = 8.02, p = .009, \eta_p^2 = .26$. All other $F_s \leq 2.32$, all other $p_s \geq .112$.

Analyses of effect propagation. The mean differences between self- and friend-related trials (at the short SOA) were 162 ms for RT1s and 161 ms for RT2. This difference was not significant, $t(23) = 0.08, p = .933, d = 0.02$. Further, the mean differences between self- and stranger-related trials were 181 ms and 176 ms for RT1 and RT2, respectively, $t(23) = 0.29, p = .775, d = 0.08$.

**** Figure 6 about here ****

**** Table 5 about here ****

Discussion.

This experiment employed the effect propagation logic (Janczyk et al., 2017; Miller & Reynolds, 2003; Kunde et al., 2012) to investigate whether the SPE has its origin in the motor stage or earlier in task processing. First, the SPE effect was clearly observed in RT1s now. As in the previous experiments, however, they were also shorter with the long than with the short SOA. Second, a similar pattern was present in RT2s, with a more pronounced effect at the short compared to the long SOA, resulting in an overadditive interaction. Finally, and most importantly, the differences between self- and friend-related trials and self- and stranger-

related trials were of equal size for both Task 1 and Task 2. In other words, the effect observed in Task 1 fully propagated into Task 2. Following the effect propagation logic, this excludes the motor stage as the source for the SPE.

General Discussion

Human often prioritize self-related information, even in case of neutral stimuli that have only recently been associated with the self (Sui et al, 2012; Sui & Humphreys, 2015): the self-prioritization effect (SPE). With the present four experiments, we aimed to pinpoint the locus of the SPE within the stream of processing by implementing SPE tasks within a PRP paradigm (Pashler, 1994). In Experiments 1-3, the SPE task was Task 2 and the SPE combined additively with SOA. In Experiment 4 we implemented an SPE task as Task 1 and the SPE now observed in Task 1 was also observed in Task 2, that is, the SPE propagated into Task 2. Our focus was on match trials, and across all experiments self-related trials were responded to faster than friend- or stranger-related trials, which in turn did not differ in their RTs. We concur that there was slightly more variation in nonmatch trials. Frankly, this variation is difficult to interpret because nonmatch trials also included self-related components. Future research may decompose the contributions of the shape and the label in such trials more thoroughly.

Theoretical implications of the results. According to the locus of slack logic (Schweickert, 1978; see Janczyk, 2013; Miller & Reynolds, 2003, for applications), the additive pattern of SPE and SOA as observed in the first three experiments excludes a pre-central stage of processing as the source for the SPE, because – with a short SOA – any change in the duration of pre-central stages becomes hidden by the cognitive slack and thus does not become visible in Task 2 RTs. This conclusion may come to a surprise, since the results of Experiment 4 of Sui et al. (2012) directly pointed to an implication of early

perceptual processing: The same perceptual brightness manipulation (that interacted with the SPE in the mentioned experiment) produced underadditivity in previous PRP studies (Pashler & Johnston, 1989). In the present study, however, no sign of underadditivity was observed. Thus, a facilitated (early) visual processing of self-related stimuli is unlikely.

This result pattern also makes two other explanations for the SPE unlikely. First, retrieval from (episodic or semantic) memory has been shown to happen in parallel to other processes (Logan & Schulkind, 2000; Logan & Delheimer, 2001). Thus, if the SPE is due to facilitated (parallel) retrieval of self-relevant information, one would have expected an underadditive interaction as well – inconsistent with the results, however. Second, self-reference acting to aid perceptual binding similar to what occurs in conjunction search tasks (Reimer, Strobach, Frensch et al., 2015; Reimer, Strobach, & Schubert, 2016) becomes unlikely for the same reason.

In addition, the effect propagation observed in Experiment 4 excludes a contribution from the motor execution stage (see Kunde et al., 2012; Miller & Reynolds, 2003, for applications). Thus, even though action plans may become prioritized in some way when associated with a self-related stimulus (Frings & Wentura, 2014), the execution of a movement itself seems not to be biased. Note, however, that this latter result is only preliminary given that we used discrete keypress responses, instead of, for example, continuous mouse movements.

Following this exclusion of possible sources for the SPE, the important question is: what are the remaining candidates? First, encoding into and switching between short-term or working memory appears to draw on central resources (Jolicoeur & Dell'Acqua, 1998; Janczyk, 2017). It might then be that self-related stimuli can be encoded into working memory faster compared with other items. Stimulus classification also appears to require

central resources (Johnston & McCann, 2006), but perhaps less so to decide that a stimulus is self-related. Finally, Garner interference also combined additively with SOA in several previous studies (Janczyk et al., 2010; Janczyk & Kunde, 2010). Garner interference is often interpreted to indicate the necessity to decompose a holistically perceived stimulus into its elements/dimensions. At least for the matching task used in Experiments 1a, 1b, 2, and 4, a possible interpretation would be that the stimulus needed to be decomposed into its components (shape and label) (Sui, Rotshtein, & Humphreys, 2013), and this decomposition is finished faster with self-related elements. This idea should be tested in future research.

These results may be surprising as it has been argued that the SPE is driven by different stages of processing (e.g., perception, attention, and decision making) that are affected by self-reference at a given task (Sui & Humphreys, 2015). For example, a recent study using diffusion modelling has shown that the SPE results from both initial decisional biases and non-decisional processes (that may even include motor execution aspects) in a personal identification task (Macrae et al., 2017). Likewise, Liu and colleagues (2016) examined the effects of facial cues (self vs. other) on the orienting of visual attention. There was both an enhanced N1 component for self-related faces and a reduced P3 component, relative to when faces of other people were presented. They argued that self-reference can enhance the saliency of stimuli (indexed by the N1 component) and subsequently facilitate responses to self-related information in decision-making (measured by the P3 component). In particular, the effect of self-reference on N1 predicts the effect on P3, indicating the integrative function of self-reference across levels of processing. One possible interpretation might be that both these processing stages are in fact capacity-limited leading to the observed additive combination of the SPE and SOA in Experiments 1-3. It might also be the case that the PRP paradigm is more sensitive to measure a single locus of an effect, for example, to

measure the processes that require divided attention (associated with the central stages), and thus may take over the effect reflecting pre-central processing. Notably, however, earlier studies have indeed reported results compatible with the idea that effects resulted from the pre-central and the central stage of processing (Janczyk, 2013; Klapötke et al., 2011).

Central bottleneck versus capacity sharing models of dual-tasking. A possible objection to our study is that we have assumed one specific dual-task model, namely the central bottleneck model (Pashler, 1994; Welford, 1952). This model is, however, not the only one in the field. As a general alternative, capacity sharing models have been suggested, where the central capacity-limited processes can run in parallel, but less efficiently if they overlap in time. The present study did not aim to distinguish dual-task models, but the first important aspect for our purpose is that in fact both central bottleneck and central capacity sharing models make the same predictions with regard to the locus of slack and the effect propagation logic (Miller & Navon, 2002; Tombu & Jolicoeur, 2003). Thus, we sketched our prediction based on the bottleneck model, which is arguably more accessible to unfamiliar readers.

However, besides that, capacity sharing models make further predictions concerning Task 1 RTs. One clear prediction is longer RTs at the short compared with at the long SOA (see Tombu & Jolicoeur, 2003, p. 9). Although not always significant, this pattern was present across all our experiments (see also Strobach, Schütz, & Schubert, 2015, for a review on SOA dependent Task 1 performance). Thus, these observations are well in line with capacity sharing models of dual-tasking. If one accepts these models, a further prediction arises for a pre-central manipulation in Task 2: At the short SOA, any Task 2 effect resulting from such a manipulation should be “inversed” in Task 1 RTs (see Tombu & Jolicoeur, 2003, p. 10). In other words, had the SPE a pre-bottleneck locus, we should have observed longer RTs in self-related trials in Task 1 at the short SOA. However, this pattern was never observed and – from

a capacity sharing point-of-view – this can be taken as additional evidence against a pre-central, perceptual locus of the SPE.

Another observation which is not compatible with the central bottleneck model is that shape (a Task 2 manipulation) had sometimes the same effect as in Task 2 also on RT1 (in match trials of Experiments 1 and 2). Response grouping can account for such observations, but it would also predict longer RT1s at the long compared with at the short SOA, that is, the opposite of what we observed. Frankly, we could only speculate about further reasons (e.g., in the context of capacity sharing models) and we prefer to refrain from interpreting these results more. Please note also that in nonmatch trials and in Experiment 3 no effect of shape on RT1s was observed.

Conclusion. In sum, the results of our experiments point to an implication of the central capacity-limited stage of processing as the source of the SPE. While our results may help to exclude some candidate processes, in particular (working) memory-based processes are still viable candidates being responsible for the SPE, among them item selection in working memory (Janczyk, 2017) and encoding into short-term memory (Jolicoeur & Dell’Acqua, 1998). Future studies may thus aim to investigate more directly the possible contribution of memory to the SPE.

References

- Brisson, B., & Jolicoeur, P. (2007). A psychological refractory period in access to visual short-term memory and the deployment of visual–spatial attention: Multitasking processing deficits revealed by event-related potentials. *Psychophysiology*, *44*, 323-333.
- Dell’Acqua, R., Job, R., Peressotti, F., & Pascali, A. (2007). The picture-work interference effect is not a Stroop effect. *Psychonomic Bulletin & Review*, *14*, 717-722.
- Durst, M., & Janczyk, M. (2018). The motor locus of the no-go based backward crosstalk. *Journal of Experimental Psychology: Learning, Memory, and Cognition*.
- Faul, F., Erdfelder, E., Lang, A.G., & Buchner, A. (2007). G* Power 3: A flexible statistical power analysis program for the social, behavioral, and biomedical sciences. *Behavior Research Methods*, *39*, 175-19
- Fuentes, L.J., Sui, J., Estevez, A.F., & Humphreys, G.W. (2015). The differential outcomes procedure can overcome self-bias in perceptual matching. *Psychonomic Bulletin & Review*, *23*, 451-458.
- Frings, C., & Wentura, D. (2014). Self-priorization processes in action and perception. *Journal of Experimental Psychology: Human Perception and Performance*, *40*, 1737-1740.
- Garner, W.R. (1978). Selective attention to attributes and to stimuli. *Journal of Experimental Psychology: General*, *107*, 287-308.
- Gronau, N., Cohen, A., & Ben-Shakhar, G. (2003). Dissociations of personally significant and task-relevant distractors inside and outside the focus of attention: A combined behavioral and psychophysiological study. *Journal of Experimental Psychology: General*, *132*, 512–529.

- Janczyk, M. (2013). Level 2 perspective taking entails two processes: Evidence from PRP experiments. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *39*, 1878-1887.
- Janczyk, M. (2017). A common capacity limitation for response and item selection in working memory. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *43*, 1690-1698.
- Janczyk, M., Franz, V.H., & Kunde, W. (2010). Grasping for parsimony: Do some motor actions escape dorsal processing? *Neuropsychologia*, *48*, 3405–3415.
- Janczyk, M., & Kunde, W. (2010). Does dorsal processing require central capacity? More evidence from the PRP paradigm. *Experimental Brain Research*, *203*, 89–100.
- Janczyk, M., Pfister, R., Wallmeier, G., & Kunde, W. (2014). Exceptions from the PRP effect? A comparison of prepared and unconditioned reflexes. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *40*, 776-786.
- Janczyk, M., Renas, S., & Durst, M. (2017). Identifying the locus of compatibility-based backward crosstalk: Evidence from an extended PRP paradigm. *Journal of Experimental Psychology: Human Perception and Performance*.
- Johnston, J.J., & McCann, R.S. (2006). On the locus of dual-task interference: Is there a bottleneck at the stimulus classification stage? *The Quarterly Journal of Experimental Psychology*, *59*, 694–719.
- Jolicoeur, P., & Dell'Acqua, R. (1998). The demonstration of short-term consolidation. *Cognitive Psychology*, *36*, 138–202.
- Keenan, J.P., McCutcheon, B., Sanders, G., Freund, S., Gallup, G.G., & Pascual-Leone, A. (1999). Left hand advantage in a self-face recognition task. *Neuropsychologia*, *37*, 1421–1425.

- Keyes, H., & Brady, N. (2010). Self-face recognition is characterized by ‘bilateral gain’ and by faster, more accurate performance which persists with faces are inverted. *The Quarterly Journal of Experimental Psychology*, *63*, 840–847.
- Klapötke, S., Krüger, D., & Mattler, U. (2011). A PRP-study to determine the locus of target priming effects. *Consciousness and Cognition*, *20*, 882–900.
- Klein, S.B., Loftus, J., & Burton, H.A. (1989). Two self-reference effects: the importance of distinguishing between self-descriptiveness judgments and autobiographical retrieval in self-referent encoding. *Journal of Personality and Social Psychology*, *56*, 853–865.
- Kunde, W., Pfister, R. & Janczyk, M. (2012). The locus of tool-transformation costs. *Journal of Experimental Psychology: Human Perception and Performance*, *38*, 703-714.
- Liu, M., He, X., Rotshtein, P., & Sui, J. (2016). Dynamically orienting your own face facilitates the automatic attraction of attention. *Cognitive Neuroscience*, *7*, 37-44.
- Logan, G.D., & Delheimer, J.A. (2001). Parallel memory retrieval in dual-task situations: II. Episodic memory. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *27*, 668-685.
- Logan, G.D., & Schulkind, M.D. (2000). Parallel memory retrieval in dual-task situations: I. Semantic memory. *Journal of Experimental Psychology: Human Perception and Performance*, *26*, 1072-1090.
- Macrae, C.N., Visokomogilski, A., Golubickis, M., Cunningham, W.A. & Sahraie, A. (2017). Self-relevance prioritizes access to visual awareness. *Journal of Experimental Psychology: Human Perception and Performance*, *43*, 438-443.
- Masson, M.E.J. (2011). A tutorial on a practical Bayesian alternative to null-hypothesis testing. *Behavior Research Methods*, *43*, 679-690.

- Miller, J., & Reynolds, A. (2003). The locus of redundant-targets and non-targets effects: Evidence from the psychological refractory period paradigm. *Journal of Experimental Psychology: Human Perception and Performance*, 29, 1126-1142.
- Paelecke, M., & Kunde, W. (2007). Action-effect codes in and before the central bottleneck: Evidence from the PRP paradigm. *Journal of Experimental Psychology: Human Perception and Performance*, 33, 627-644.
- Pashler, H. (1994). Dual-task interference in simple tasks: Data and theory. *Psychological Bulletin*, 116, 220-244.
- Pashler, H., & Johnston, J.C. (1989). Chronometric evidence for central postponement in temporally overlapping tasks. *The Quarterly Journal of Experimental Psychology*, 41, 19-45.
- Reimer, C.B., Strobach, T., Frensch, P., & Schubert, T. (2015). Are processing limitations of visual attention and response selection subject to the same bottleneck in dual-tasks? *Attention, Perception, & Psychophysics*, 77(4), 1052-1069.
- Reimer, C.B., Strobach, T., & Schubert, T. (2016). Concurrent deployment of visual attention and response selection bottleneck in a dual-task: Electrophysiological and behavioural evidence. *The Quarterly Journal of Experimental Psychology*. doi:10.1080/17470218.2016.1245348
- Schäfer, S., Wentura, D., & Frings, C. (2015). Self-prioritization beyond perception. *Experimental Psychology*, 62, 415-425.
- Schweickert, R. (1978). A critical path generalization of the additive factor method: Analysis of a stroop task. *Journal of Mathematical Psychology*, 18, 105-139.
- Rasch, B., Friese, M., Hofmann, W., & Naumann, E. (2010). *Quantitative Methoden. Band 2*. Berlin: Springer.

- Reuther, J., & Chakravathi, R. (2017). Does self-prioritization affect perceptual processes? *Visual Cognition, 25*, 381-398.
- Sternberg, S. (1969). The discovery of processing stages: Extensions of Donders' method. *Acta Psychologica, 30*, 276-315.
- Sui, J., He, X., & Humphreys, G.W. (2012). Perceptual effects of social salience: Evidence from self-prioritization effects on perceptual matching. *Journal of Experimental Psychology, Human Perception and Performance, 38*, 1105-1117.
- Sui, J., & Humphreys, G.W. (2013). Self-referential processing is distinct from semantic elaboration: Evidence from long-term memory effects in a patient with amnesia and semantic impairments. *Neuropsychologia, 51*, 2663-2673.
- Sui, J., & Humphreys, G.W. (2015). The integrative self: How self-reference integrates perception and memory. *Trends in Cognitive Sciences, 19*, 719-728.
- Sui, J., & Humphreys, G.W. (2017). Aging enhances cognitive biases to friends but not the self. *Psychonomic Bulletin & Review*. doi:10.3758/s13423-017-1264-1.
- Sui, J., Rotshtein, P., & Humphreys, G. W. (2013). Coupling social attention to the self forms a network for personal significance. *Proceedings of the National Academy of Sciences of the United States of America, 110*, 7607-7612.
- Sui, J., Yankouskaya, A. & Humphreys, G. W. (2015). Super-capacity and violations of race independence for self- but not for reward-associated stimuli. *Journal of Experimental Psychology, Human Perception and Performance, 41*, 441-452.
- Stein, T., Siebold, A., & van Zoest, W. (2016). Testing the idea of privileged awareness of self-relevant information. *Journal of Experimental Psychology: Human Perception and Performance, 42*, 303-307.
- Strobach, T., Schütz, A., & Schubert, T. (2015). On the importance of Task 1 and error performance measures in PRP dual-task studies. *Frontiers in Psychology, 6*, 403.

- Symons, C.S., & Johnson, B.T. (1997). The self-reference effect in memory: A meta-analysis. *Psychological Bulletin*, *121*, 371–394.
- Telford, C.W. (1931). The refractory phase of voluntary and associative responses. *Journal of Experimental Psychology*, *14*, 1-36.
- Wagenmakers, E.-J. (2007). A practical solution to the pervasive problems of p values. *Psychonomic Bulletin & Review*, *14*, 779-804.
- Welford, A.T. (1952). The ‘psychological refractory period’ and the timing of high-speed performance – A review and a theory. *British Journal of Psychology*, *43*, 2-19.
- Wieki, T.V., Sofer, I., & Frank, M.J. (2013). HDDM: Hierarchical Bayesian estimation of the drift-diffusion model in python. *Frontiers in Neuroinformatics*, *7*, 14. doi: 10.3389/fninf.2013.00014.

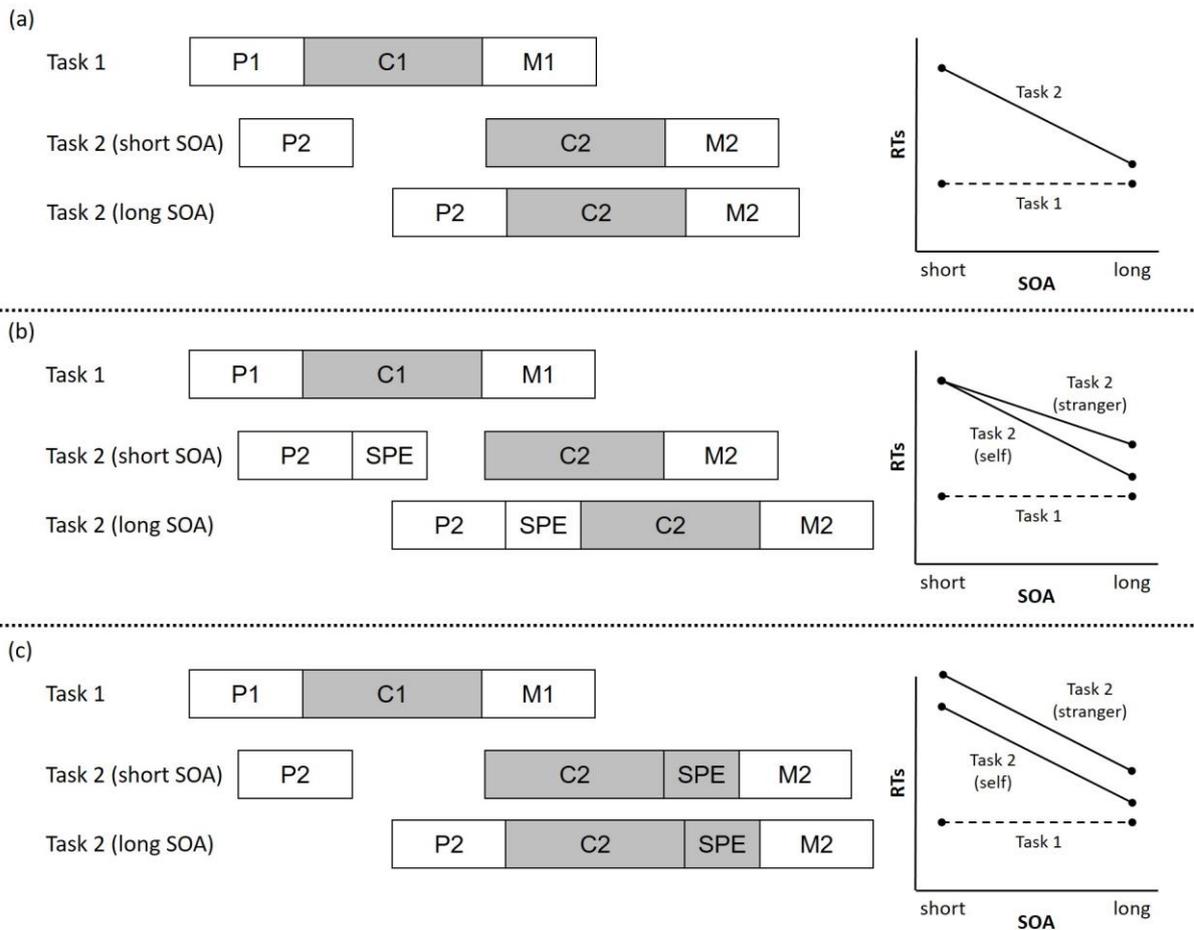
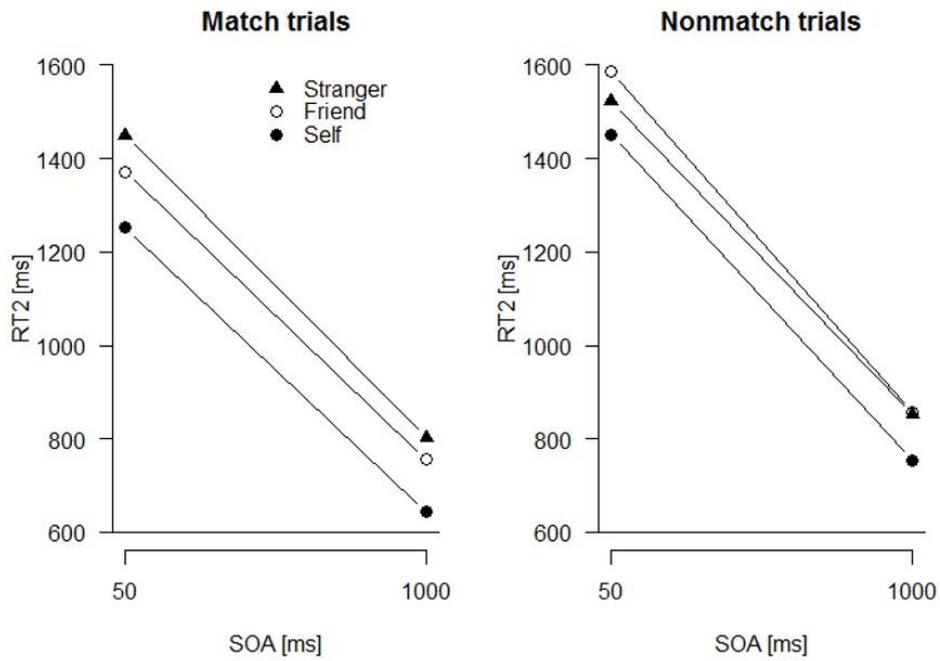


Figure 1. Illustration of the central bottleneck model and the predictions for RTs: (a) processing of Tasks 1 and 2 without experimental manipulations except for stimulus onset asynchrony (SOA), (b) processing of Tasks 1 and 2 when the SPE arises from the pre-central stage of Task 2 resulting in an underadditive interaction of the SPE and the SOA, and (c) processing of Tasks 1 and 2 when the SPE arises from the central stage of Task 2 (or from its post-central stage) resulting in an additive combination of the SPE and the SOA. (P = pre-central perceptual stage, C = central stage, M = post-central motor stage, SPE = self-prioritization effect; for further explanations, please see text)

Experiment 1a



Experiment 1b

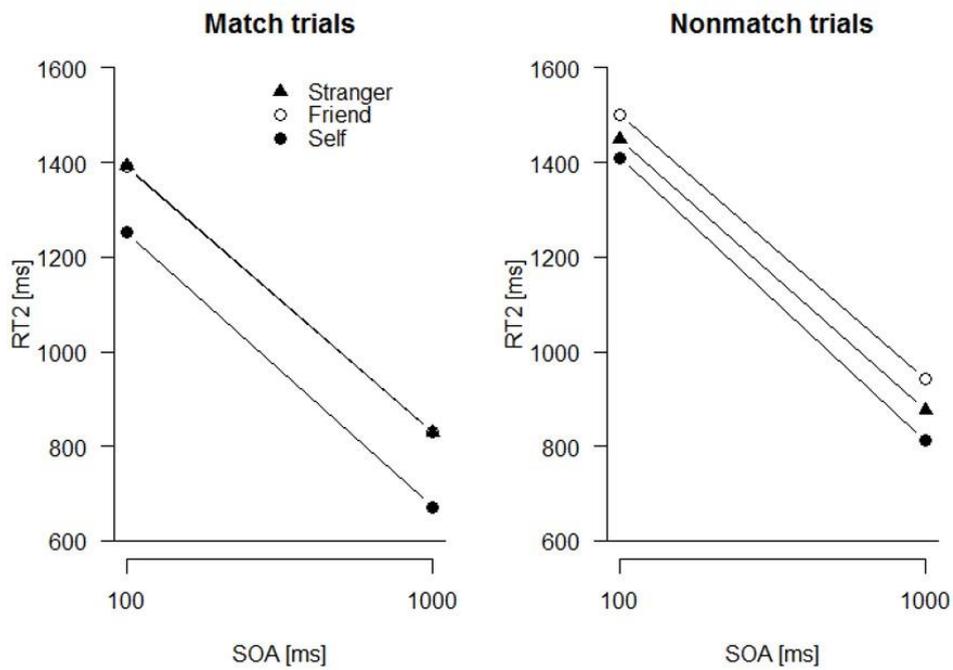


Figure 2. Mean Task 2 response times (RT2) in milliseconds (ms) of Experiments 1a (upper panels) and 1b (lower panels) for match trials (left panels) and nonmatch trials (right panels) as a function of shape category and stimulus onset asynchrony (SOA).

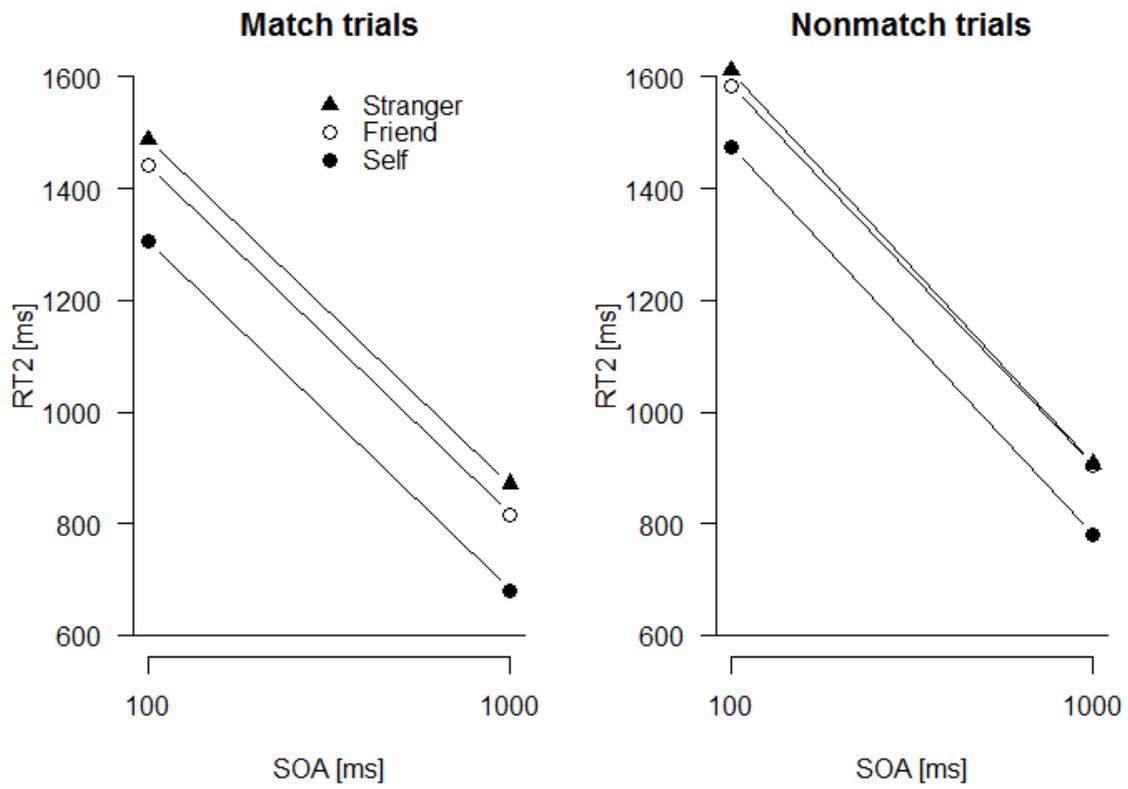


Figure 3. Mean Task 2 response times (RT2) in milliseconds (ms) of Experiment 2 for match trials (left panel) and nonmatch trials (right panel) as a function of shape category and stimulus onset asynchrony (SOA).

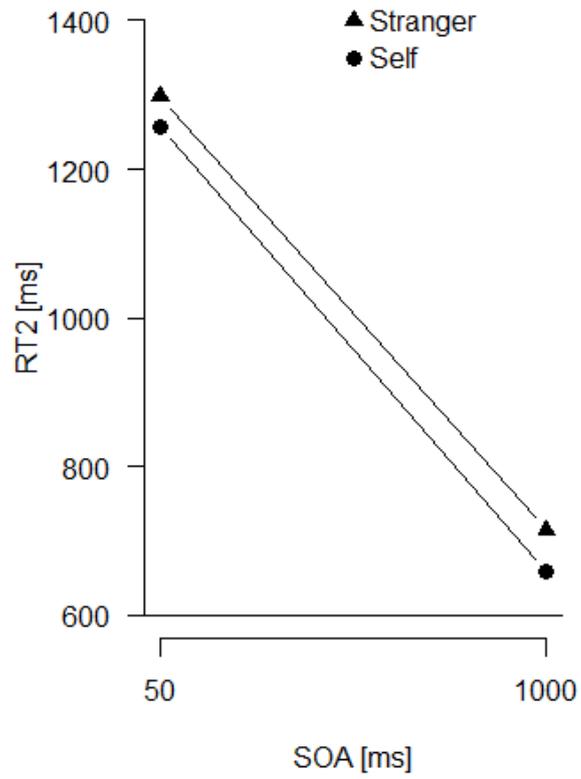


Figure 4. Mean Task 2 response times (RT2) in milliseconds (ms) of Experiment 3 as a function of shape category and stimulus onset asynchrony (SOA).

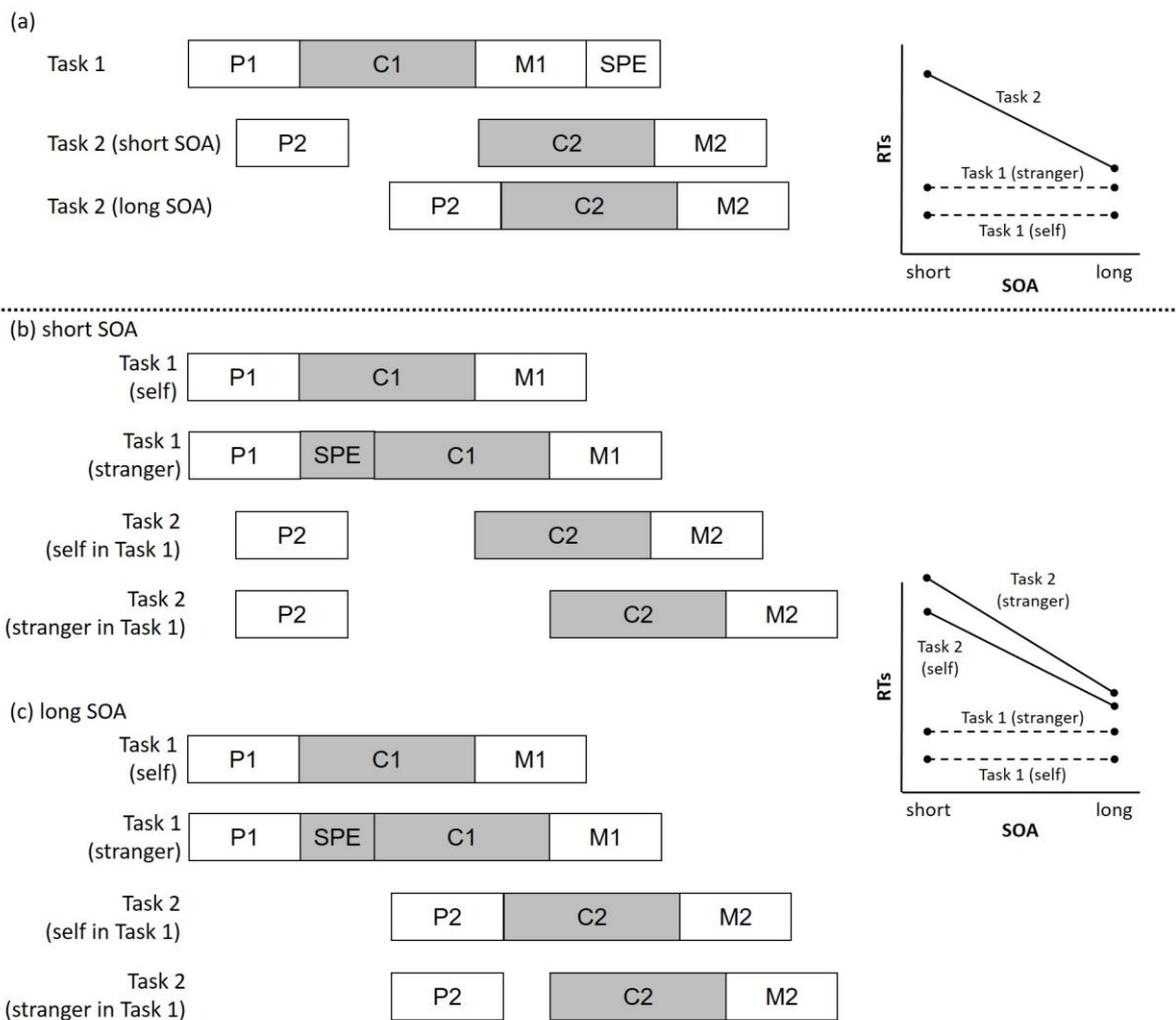


Figure 5. Illustration of the effect propagation logic and the predictions for RTs: (a) Processing of Tasks 1 and 2 when the SPE arises from the post-central motor stage of Task 1. In this case, the SPE occurs in Task 1 RTs, but not in Task 2 RTs. (b) and (c) Processing of Tasks 1 and 2 when the SPE arises from the central stage of Task 1 (or from its pre-central perceptual stage). Panel (b) illustrates a short stimulus onset asynchrony (SOA) where the SPE observed in Task 1 RTs is observed with the same size in Task 2 RTs, which is often considered the most important data pattern in effect propagation experiments. Panel (c) illustrates additionally the long SOA where the (propagated) SPE is smaller in Task 2 or even absent (depending on the actual SOA values). In sum, an overadditive interaction of the (propagated) SPE and the SOA is predicted. (P = pre-central perceptual stage, C = central stage, M = post-central motor stage, SPE = self-prioritization effect; for further explanations, please see text)

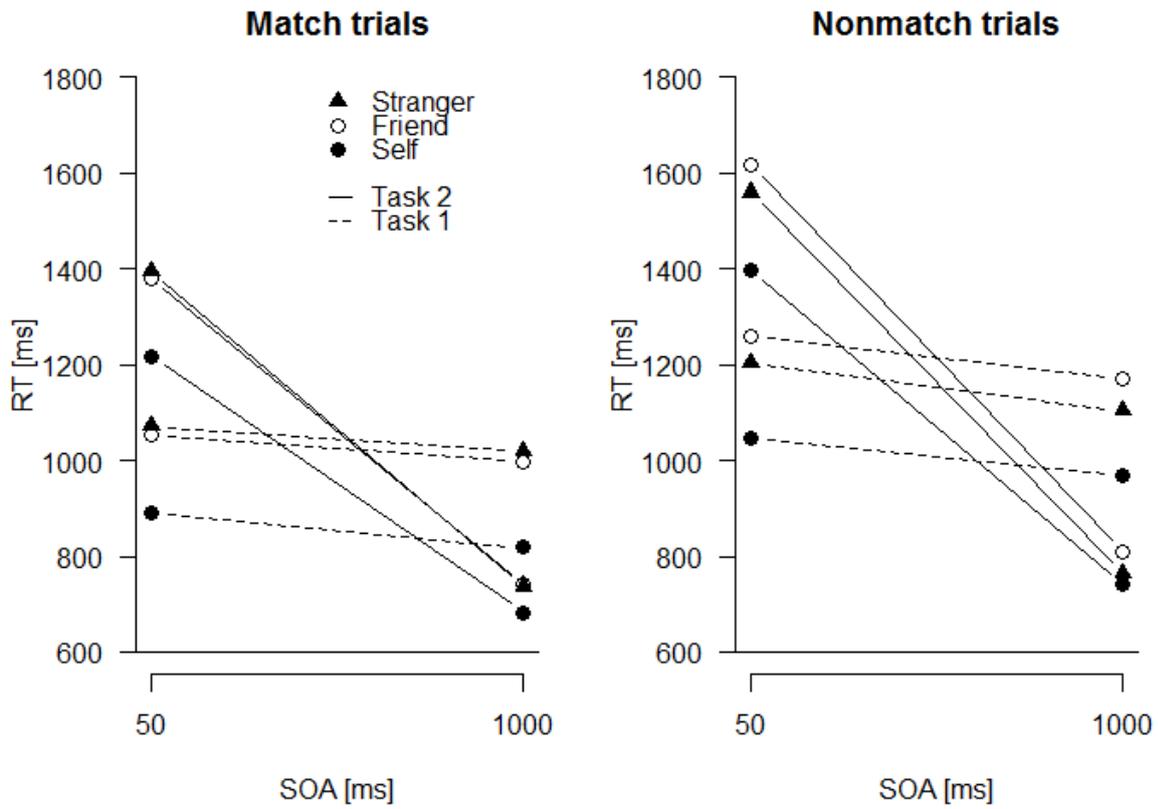


Figure 6. Mean response times (RTs) in milliseconds (ms) of Experiment 4 for match trials (left panel) and nonmatch trials (right panel) as a function of shape category, stimulus onset asynchrony (SOA; in ms), and task.

Table 1. Mean response times (RT) in milliseconds (ms) and percentages error (PE) for Task 2 and 1 in Experiment 1a as a function of shape category, match, and stimulus onset asynchrony (SOA).

		RT2 [ms]		PE2		RT1 [ms]		PE1	
		SOA [ms]		SOA [ms]		SOA [ms]		SOA [ms]	
		50	1000	50	1000	50	1000	50	1000
S2 match	S2 shape								
	category								
match	self	1253	643	7.38	5.02	1051	907	5.58	1.67
	friend	1372	756	10.61	8.16	1118	916	3.50	2.78
	stranger	1450	800	15.74	13.00	1161	918	6.15	1.71
nonmatch	self	1450	753	8.45	8.95	1182	905	4.61	1.71
	friend	1587	857	13.65	10.44	1258	911	5.84	2.93
	stranger	1521	851	11.15	9.21	1213	929	6.32	1.56

Table 2. Mean response times (RT) in milliseconds (ms) and percentages error (PE) for Task 2 and 1 in Experiment 1b as a function of shape category, match, and stimulus onset asynchrony (SOA).

		RT2 [ms]		PE2		RT1 [ms]		PE1	
		SOA [ms]		SOA [ms]		SOA [ms]		SOA [ms]	
		100	1000	100	1000	100	1000	100	1000
S2 match	S2 shape								
	category								
match	self	1252	672	4.78	4.91	1025	850	5.16	1.54
	friend	1391	830	10.34	9.25	1109	878	4.17	1.81
	stranger	1392	828	11.79	12.08	1087	846	4.92	1.30
nonmatch	self	1410	811	12.29	12.01	1060	854	5.59	2.50
	friend	1501	943	15.35	12.98	1143	863	4.45	1.68
	stranger	1449	875	10.32	5.47	1095	855	5.20	2.64

Table 3. Mean response times (RT) in milliseconds (ms) and percentages error (PE) for Task 2 and 1 in Experiment 2 as a function of shape category, match, and stimulus onset asynchrony (SOA).

		RT2 [ms]		PE2		RT1 [ms]		PE1	
		SOA [ms]		SOA [ms]		SOA [ms]		SOA [ms]	
		100	1000	100	1000	100	1000	100	1000
S2 match	S2 shape								
	category								
match	self	1306	680	3.89	2.36	1078	1075	3.19	1.11
	friend	1441	816	8.91	8.76	1139	1101	2.37	0.69
	stranger	1487	871	11.27	12.23	1131	1114	2.65	0.69
nonmatch	self	1476	780	8.51	8.33	1171	1091	4.05	1.53
	friend	1582	904	9.06	10.34	1211	1105	2.93	1.39
	stranger	1610	907	10.97	7.38	1224	1092	3.75	0.69

Table 4. Mean response times (RT) in milliseconds (ms) and percentages error (PE) for Tasks 2 and 1 in Experiment 3 as a function of category category and stimulus onset asynchrony (SOA).

	RT2 [ms]		PE2		RT1 [ms]		PE1	
	SOA [ms]		SOA [ms]		SOA [ms]		SOA [ms]	
	50	1000	50	1000	50	1000	50	1000
S2 shape								
category								
self	1255	657	3.62	3.11	962	895	2.95	1.52
stranger	1295	713	3.89	2.98	970	888	2.55	1.27

Table 5. Mean response times (RT) in milliseconds (ms) and percentages error (PE) for Task 2 and 1 in Experiment 4 as a function of shape category, match, and stimulus onset asynchrony.

		RT2 [ms]		PE2		RT1 [ms]		PE1	
		SOA [ms]		SOA [ms]		SOA [ms]		SOA [ms]	
		50	1000	50	1000	50	1000	50	1000
S2 match	S2 shape								
	category								
match	self	1218	682	2.78	1.55	891	818	2.92	3.66
	friend	1379	743	3.38	1.81	1053	998	3.20	2.92
	stranger	1395	738	3.89	2.38	1071	1020	5.00	5.46
nonmatch	self	1398	741	2.23	3.62	1048	969	6.96	6.56
	friend	1616	811	5.28	3.22	1260	1172	11.25	9.06
	stranger	1560	765	4.32	3.07	1202	1104	7.51	7.75

Appendix A

Table A1. Inferential statistics for the three-way ANOVAs on Experiment 1a RT data

Effect (dfs)	Task 1			Task 2		
	<i>F</i>	<i>p</i>	η_p^2	<i>F</i>	<i>P</i>	η_p^2
SOA (1, 23)	35.38	< .001	.61	712.58	< .001	.97
Shape category (2, 46)	5.77	.006	.20	27.02	< .001	.54
Match (1, 23)	16.75	< .001	.42	49.47	< .001	.68
SOA × Shape category (2, 46)	3.23	.049	.12	0.23	.735 ($\epsilon = .75$)	.01
SOA × Match (1, 23)	12.54	.002	.35	11.41	.003	.33
Shape category × Match (2, 46)	2.08	.136	.08	11.75	< .001	.34
SOA × Shape category × Match (2, 46)	2.73	.076	.11	2.69	.079	.10

Table A2. Inferential statistics for the three-way ANOVAs on Experiment 1b RT data

Effect (dfs)	Task 1			Task 2		
	<i>F</i>	<i>p</i>	η_p^2	<i>F</i>	<i>P</i>	η_p^2
SOA (1, 23)	32.58	< .001	.59	303.00	< .001	.93
Shape category (2, 46)	9.33	< .001	.29	25.89	< .001	.53
Match (1, 23)	8.70	.007	.27	72.64	< .001	.76
SOA × Shape category (2, 46)	1.33	.275	.05	1.14	.327	.05
SOA × Match (1, 23)	6.53	.018	.22	0.38	.544	.02
Shape category × Match (2, 46)	1.45	.244	.06	8.45	< .001	.27
SOA × Shape category × Match (2, 46)	2.52	.092	.10	0.14	.825 ($\epsilon = .80$)	.01

Table A3. Inferential statistics for the three-way ANOVAs on Experiment 2 RT data

Effect (dfs)	Task 1			Task 2		
	<i>F</i>	<i>p</i>	η_p^2	<i>F</i>	<i>P</i>	η_p^2
SOA (1, 23)	1.55	.225	.06	668.16	< .001	.97
Shape category (2, 46)	3.89	.041	.14	33.55	< .001	.59
Match (1, 23)	14.69	.001	.39	42.73	< .001	.65
SOA × Shape category (2, 46)	1.36	.266	.06	0.09	.916	< .01
SOA × Match (1, 23)	16.66	< .001	.42	9.02	.006	.28
Shape category × Match (2, 46)	0.58	.566	.02	2.15	.128	.09
SOA × Shape category × Match (2, 46)	0.88	.421	.04	0.51	.602	.02

Table A4. Inferential statistics for the three-way ANOVAs on Experiment 4 RT data

Effect (dfs)	Task 1			Task 2		
	<i>F</i>	<i>p</i>	η_p^2	<i>F</i>	<i>P</i>	η_p^2
SOA (1, 23)	17.90	< .001	.44	1338.44	< .001	.98
Shape category (2, 46)	27.90	< .001	.55	24.17	< .001	.51
Match (1, 23)	79.57	< .001	.78	72.86	< .001	.76
SOA × Shape category (2, 46)	0.03	.974	< .01	14.82	< .001	.39
SOA × Match (1, 23)	4.26	.050	.16	93.93	< .001	.80
Shape category × Match (2, 46)	3.80	.030	.14	2.33	.109	.09
SOA × Shape category × Match (2, 46)	0.38	.686	.02	0.51	.603	.02