**Reliability of Self-Prioritization Effect as Measured by the Perceptual Matching Task: Evidence from Multiple Datasets**

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***Abstract***: The self-prioritization effect (SPE) refers to the effect that performance on cognitive tasks is better when stimuli are related to the self than when they are not. In the last decade, the self-perceptual matching task (SPMT) has emerged as a mainstream paradigm for studying SPE due to its simplicity and elimination of familiarity effects. As a simple button-pressing task, SPMT yields two outcomes for quantifying SPE: reaction time and accuracy. Other SPE indices derived from reaction times and accuracy are also reported in the literature, including sensitivity *d’* under signal-detection theory, the efficiency index through a direct division between reaction times and accuracy, drift rate (*v*) and starting point (*z*) estimated using the drift-diffusion models. In addition, the calculation of the SPE can be based on different baseline conditions, including “Close”, “Stranger”, “Celebrity”, and “NonPerson”. However, the reliability of these SPE indices remains unexplored. To fill the gap, we conducted a pre-registered study wherein we re-analyzed 18 datasets from 11 papers (N = 15) using the split-half reliability and intraclass correlation coefficient (ICC). The results revealed that the split-half reliabilities of RT (yiClose = 0.58; yiStranger = 0.60) and Efficiency (yiClose = 0.52; yiStranger = 0.58) are relatively high but still lower than that required in psychometrics. The estimated split-half reliabilities for the other four indices are approximately 0.5 or even lower. For the ICC2, which measures individual level, the reaction time (ICC2kClose = 0.53; ICC2kStranger = 0.58) and efficiency (ICC2kClose = 0.52; ICC2kStranger = 0.34) are relatively low. However, for the ICC2k, which measures group level, the reaction time (ICC2kClose = 0.87; ICC2kStranger = 0.89) and efficiency (ICC2kClose = 0.86; ICC2kStranger = 0.76) are relatively high. This suggests that the SEP based on reaction time and efficiency is only reliable at the group level. When used to measure individual level, further exploration is still needed. These results provide valuable insights for a deeper understanding of the reliability of the SPMT and its potential future applications.

***Keywords***: Self-Prioritization Effect (SPE), Self-Perceptual Matching Task (SPMT), Reliability, Multiverse

# **1 Introduction**

The Self-Prioritization Effect (SPE) refers to the phenomenon whereby performance in cognitive tasks is better when stimuli are related to the self than when they are not. This effect has been widely documented and confirmed since the 1950s. In the early days of cognitive psychology, researchers found that subjects were able to recognize their own names, even when they were mixed with a noisy auditory background and not the target of the task in dichotic listening tasks (Cherry, 1953; Moray, 1959). SPE effect was then reported in memory research by Craik and Tulving (1975), who found that participants were able to recall more words when they were related to the self compared to when they were processed at other levels (e.g., semantic). This SPE effect in memory was then replicated by many others (Conway & Dewhurst, 1995; Rogers et al., 1977; Symons & Johnson, 1997). In the following decades, the SPE has also been found to occur with different stimuli, such own face (Keenan et al., 2000; Kircher et al., 2000; Turk et al., 2002), own voice (Hughes & Harrison, 2013; Payne et al., 2021), own name (Constable, Rajsic, et al., 2019), and newly owned object (Strachan et al., 2020). SPE was found across a variety of cognitive tasks, such as perceptual task (Cunningham & Turk, 2017; Desebrock et al., 2018), decision-making task (Sui & Humphreys, 2013), attentional task (Shapiro et al., 1997), and ownership task (Cunningham et al., 2008).

Although SPE is often argued to be a self-specific effect, it can be challenging to disassociate it from the familiarity effect since most studies use stimuli owned by participants or by others. Sui et al. (2012) proposed a paradigm where participants first associate geometrical shapes (e.g., triangle, square, and circle) with labels of persons (e.g., "You," "friend," and "stranger") and then perform a perceptual matching task in which they decide if the shape-label pairs presented on the screen match the learned association or not (Sui et al., 2012). Because the task requires participants to learn the social meaning of different geometric shapes, it is called the Self-Perceptual Matching Task (SPMT). In this task, Sui et al. (2012) found that shapes associated with the self are performed better, with faster response times, better accuracy, and/or higher sensitivity scores, compared to shapes associated with friends and strangers. Because the self-relatedness is acquired immediately right before they start the perceptual matching task, this paradigm eliminated the effect of familiarity of the stimuli.

Since then, the SPMT has become the mainstream method for investigating the mechanism underlying the SPE. For instance, researchers have explored the importance of personality traits in identity labels (Golubickis et al., 2020), the self-relevant labels that include the past, present, and future self (Golubickis et al., 2017), as well as "good self" and "bad self" labels (Hu et al., 2020), and the group advantage effect of in-group labels (Constable, Elekes, et al., 2019; Constable & Knoblich, 2020; Enock et al., 2018; Enock et al., 2020). Moreover, the SPMT has been applied to various fields. In neuroscience and physiology, researchers investigate which brain regions are activated during self-prioritization effect (Feng et al., 2018; Humphreys & Sui, 2015), and gender differences in self-prioritization effect due to oxytocin (Feng et al., 2020). In clinical research, SPMT has been used to understand atypical self-processing in populations such as those with autism or depression (Gillespie‐Smith et al., 2018; Nijhof & Bird, 2019; Sui & Humphreys, 2017). Cross-cultural studies have shown that individuals from individualistic cultures demonstrate a stronger self-prioritization effect (Jiang et al., 2019), and that the language of the experimental stimuli can affect the strength of the effect (Ivaz et al., 2016). Finally, the SPMT has also been applied to child development, with studies examining developmental changes in self-positivity effects (Maire et al., 2020; Zhou et al., 2019).

While SPMT has gained widespread adoption as a prominent method for investigating the underlying mechanism of the self-prioritization effect, there has been microscopic examination and report of the psychometric properties of the outcomes, necessitating a careful evaluation. (Parsons et al., 2019; Zorowitz & Niv, 2023). Given the increasing use of SPMT to assess individual differences in fields such as psychiatry (Liu et al., 2022) and social psychology (Enock et al., 2018). it is crucial to ensure a high degree of measurement consistency to accurately assess human perceptual abilities (Parsons et al., 2019). Furthermore, in tasks as simple as the SPMT, there are multiple approaches to quantify the self-prioritization effect. These include two direct measures based on SPMT, namely reaction times (RT) and accuracy (ACC), as well as derived measures such as efficiency (Humphreys & Sui, 2015; Stoeber & Eysenck, 2008), *d* prime of Signal Detection Theory (SDT) (Hu et al., 2020; Sui et al., 2012), and drift rate (*v*) and starting point (*z*) from Drift Diffusion Model (DDM) (Golubickis et al., 2017).

To address the existing research gap, the present study investigated the reliability of self-prioritization effect (SPE) indices in the self-perceptual matching task (SPMT). We examined six SPE indices as mentioned earlier, that are supposed to capture the disparity between self-related and other-related stimuli of the matching trials. This was achieved by reanalyzing data obtained from previous studies that employed SPMT. Given the diverse methods available for evaluating the reliability of cognitive tasks, we employed both the Split-Half Reliability and Intraclass Correlation Coefficient (ICC) to determine the reliability of each SPE index. These findings deepen our understanding the reliability of SPE as measured by SPMT and facilitate the future usage of SPMT.

# **2 Methods**

## 2.1 Ethics information

## This research relied on secondary data, therefore informed consent is not applicable here.

## 2.2 Datasets

Below, we first provided a brief overview of the original experimental design of SPMT, as described in the Experiment 1 by Sui et al. (2012). Then, we gave an overview of 18 datasets used in the current analysis.

The original SPMT used a 2 by 3 within-subject design. The first independent variable, labeled “Matching,” consisted of two levels: “Matching” and “Nonmatching,” indicating whether the shape and label were congruent. The second independent variable, labeled “Identity,” comprised three levels: “Self”, “Friend”, and “Stranger”, representing the corresponding identity associated with the shape.

The procedure of original SPMT consisted of two phases (see Fig. 1). In the first phase (learning phase), participants completed a learning task in which they associated three geometric shapes (circle, triangle and square) with three labels (self, friend, and stranger) for approximately 60 seconds. The shape-label associations were balanced across participants. In the second phase (formal experimental phase), participants completed a perceptual matching task. Each trial started with a fixation cross displayed in the center of the screen for 500 ms, followed by a shape-label pairing and fixation cross for 100 ms. the screen then went blank for 1500 ms, or until a response was made. Participants were required to judge whether the presented shape and label matched the learned associations from the learning phase and respond as quickly and accurately as possible by pressing one of two buttons within the allotted timeframe. Prior to the formal experimental phase, participants completed a training session consisting of 24 practice trials. After the training, participants completed six blocks of 60 trials in the matching task, with two matching types (matching/nonmatching) and three shape associations, for a total of 60 trials per association. Short breaks lasting up to 60 seconds were provided after each block.



**Fig. 1.** Procedure of the original SPMT in the Experiment 1 (Sui et al., 2012).*Note*: The relation between shape-label pairs is counter-balanced between participants.

In this study, we collected a total of 18 datasets from 11 research articles, and one from our laboratory (Hu et al., 2023). and one from our collaborators (Liu et al., 2023), that included raw data from empirical studies utilizing the SPMT. These datasets were included in the analysis based on two criteria: (1) the experimental design did not deviate from the original SPMT of Sui et al. (2012); (2) the trial-level data is available, which is necessary for estimating at least one reliability index. Seven studies opened their raw data publicly (Constable et al., 2021; Constable & Knoblich, 2020; Golubickis & Macrae, 2021; Navon & Makovski, 2021; Qian et al., 2020; Schäfer & Frings, 2019; Svensson et al., 2022) and did not deviate from the original experimental paradigm. Additionally, we included data from four articles that obtained from the authors upon request (Bukowski et al., 2021; Cheng & Tseng, 2019; Kolvoort et al., 2020; Martínez-Pérez et al., 2020; Woźniak et al., 2018; Xu et al., 2021). One article indicated that data were shared on the Open Science Framework (OSF) platform (https://osf.io/pcv3u/), but the repository was empty (Bukowski et al., 2021), thus cannot be included in the current analysis.

It is worth noting that the current research culture discourages direct replications (Makel et al., 2012), which may explains why all datasets included in our analysis involved some degree of modification to the original design, such as incorporating additional independent variables or using different experimental materials (see our preregistration for details). Also note that Intraclass Correlation Coefficients (ICC) were calculated only if there were test-retest data, otherwise only coefficients for split-half reliability were estimated. The details of these included datasets are described in Table 1.

Table 1. Dataset Information

| Paper | Exp. | Independent Variable | | | | Sample  Size | # of Trials per Condition | Self-Prioritization Effect Indices | | | | | | Reliability | |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| IV 1 | IV 2 | IV 3 | IV 4 | RT | ACC | d | Eff | v | z | ICC | SHR |
| Hu et al. (2023) | 1 | Matching | Identity | Emotion  **Control**, Neutral,  Happy, Sad | Session | 33 | 60 | √ | √ | √ | √ | √ | √ | √ | √ |
| Constable and Knoblich (2020) | 1 | Matching | Identity | Switch Identity  Partner, Stranger | Phase  **1**; 2 | 46 | 20 | √ | √ | √ | √ | √ | √ |  | √ |
| Constable et al. (2021) | 2 | Matching | Identity  Self; Stranger |  |  | 56 | 48 | √ | √ | √ | √ | √ | √ |  | √ |
| Qian et al. (2020) | 1 | Matching | Identity Self; Celebrity; Stranger | Mood (Session) |  | 24 | 24 | √ | √ | √ | √ | √ | √ |  | √ |
| 2 | Matching | Identity Self; Celebrity | Cue  With, **Without** |  | 25 | 25 | √ | √ | √ | √ | √ | √ |  | √ |
| Schäfer and Frings (2019) | 1 | Matching | Identity Self; Mother; Acquaintance/none |  |  | 32 | 18 | √ | √ | √ | √ | √ | √ |  | √ |
| 3 | Matching | Identity Self; Mother; Acquaintance |  |  | 35 | 24 | √ | √ | √ | √ | √ | √ |  | √ |
| Golubickis and Macrae (2021) | 1 | Matching | Identity | Presentation **Mixed;** Blocked |  | 30 | 30 | √ | √ | √ | √ | √ | √ |  | √ |
| Navon and Makovski (2021) | 1 | Matching | Identity |  |  | 13 | 60 | √ | √ | √ | √ | √ | √ |  | √ |
| 3 | Matching | Identity  Self; Father; Stranger |  |  | 28 | 60 | √ | √ | √ | √ | √ | √ |  | √ |
| 4 | Matching | Identity |  |  | 27 | 60 | √ | √ | √ | √ | √ | √ |  | √ |
| Svensson et al. (2022) | 1 | Matching | Identity Self; Friend |  |  | 20 | 50 | √ | √ | √ | √ | √ | √ |  | √ |
| 2 | Matching | Identity Self; Friend | Frequency  self > friend |  | 24 | 100 | √ | √ | √ | √ | √ | √ |  | √ |
| 3 | Matching | Identity Self; Friend | Frequency  self < friend |  | 25 | 100 | √ | √ | √ | √ | √ | √ |  | √ |
| Xu et al. (2021) | 1 | Matching | Identity | Feedback | Sex | 105 | 60 | √ | √ | √ | √ | √ | √ |  | √ |
| Woźniak et al. (2018) | 1 | Matching | Identity | Facial Gender  Mele; Female |  | 18 | 56 | √ | √ | √ | √ | √ | √ |  | √ |
| 2 | Matching | Identity | Facial Gender  Mele; Female |  | 18 | 60 | √ | √ | √ | √ | √ | √ |  | √ |
| Liu et al. (2023) | 1 | Matching | Identity  Self; Stranger |  |  | 298 | 16 | √ | √ | √ | √ | √ | √ |  | √ |

Note. SPE: Self-Prioritization Effect, ICC: Intraclass Correlation Coefficient, SHR: Split-Half Reliability. For IV3 and IV4, we only included the conditions that are similar to the original design in Sui et al. (2012), which were highlighted in BOLD font.

## 2.3 Analysis



**Fig. 2** Roadmap of the current study. SPE: self-prioritization effect; d-prime is the sensitivity index under the Signal Detection Theory; drift rate (v) and starting point (z) are parameters derived from the Drift-diffusion Model; ICC: Intraclass Correlation Coefficient, SHR: Split-half Reliability.

All analyses in this paper were performed using the statistical software R (R Core Team, 2023). The research flow of the current study is visually represented in Fig. 2. After collecting the data, we performed data cleaning and calculated the six indices' SPE separately for different targets. Finally, we calculated the split-half reliabilities of these SPE values. If there were test-retest data, we would also calculate the test-retest reliability using the intraclass correlation coefficient (ICC).

### 2.3.1 Data pre-processing

In total, we gathered 18 publicly available datasets, as mentioned earlier and presented in Table 1. We used the following criteria for data exclusion:

1. Participant exclusion criteria
2. Participants who had wrong trial numbers because of procedure errors is excluded from the analysis,
3. Participants with an overall accuracy < 0.5 is excluded from the analysis,
4. Participants with any of the conditions with zero accuracy is excluded from the analysis.
5. Behavioural data exclusion criteria
6. Trials with no response or wrong key press is excluded from the analysis,
7. The practice trials are excluded from the formal analysis,
8. Participants with any of the conditions with zero accuracy is excluded from the analysis,
9. The data under conditions other than the “control condition” would not be used in the current study.

### 2.3.2 Calculating the SPE

For each dataset, we calculated six indices for each experimental condition: Mean Reaction Time (RT), Accuracy (ACC), *d* prime (*d′*), Efficiency (*η*), Drift Rate (*v*), and Starting Point (*z*). RT and ACC are obtained directly from the datasets, while *d′* and *η* are calculated based on RT and ACC (see Table 2). Please note that the condition “Other” may vary across studies, we calculated the SPE for each “Other” condition. More specifically, we calculated the differences for “Self vs Close”, “Self vs Stranger”, “Self vs Celebrity” and “Self vs NonPerson”.

Table 2. Indices in SPMT and corresponding calculation of indices and SPE

| **Indices** | **Indices Calculation** | **SPE Calculation Based on Indices** | **Source** |
| --- | --- | --- | --- |
| Mean  Reaction Times  (RT) |  |  | Sui et al. (2012) |
| Accuracy (ACC) |  |  | Sui et al. (2012) |
| *d* prime |  |  | Sui et al. (2012) |
| Efficiency |  |  | Humphreys and Sui (2015); Stoeber and Eysenck (2008) |
| Drift Rate (*v*) | DDM：parameters will be identified through default model |  | Golubickis et al. (2017) |
| Starting Point (*z*) |  | Golubickis et al. (2017) |

Note. DDM: Drift Diffusion Model.

### 2.3.3 Estimating the Reliability

**Split-half reliability.** We calculated the split-half reliability of the six indices using four different ways splitting the data: first-second, odd-even, permutated, and Monte Carlo (Kahveci et al., 2022; Pronk et al., 2022). The first-second split-half reliability divides the first and second halves of trials, while the odd-even split-half reliability divides trials into odd and even numbered sequences. And the permutation split shuffles the trial order and randomly assigns each half to a group. The Monte Carlo split-half is similar to the permutated split-half, but it repeats the process thousands of times to calculate the average and 95% confidence interval of the split-half reliability.

First, the data were stratified per condition (Pronk et al., 2022) and then split into two halves. For example, when using Monte Carlo Split-Half, we randomly split the stratified data into two halves for 5000 times, which resulted in 5000 pairs of two halves of the data. Next, we calculated 5000 Pearson correlation coefficients based on these 5000 pairs of data and calculated the mean and 95% confidence interval of the 5000 correlations coefficients. The first-second split, odd-even split, and permutated split are similar to Monte Carlo method, but each only resulted in one reliability coefficient. Finally, due to each dataset receiving a split-half reliability coefficient, and significant variations in the number of trials and split-half reliability across datasets, we employed a meta-analytic approach to obtain a more accurate estimation of the average split-half reliability. As stated by Kucina et al. (2023), Trial numbers has a significant impact on the reliability of cognitive experiments, with higher trial numbers leading to increased reliability (see also Supplementary Fig. 5). Therefore, we believe that assigning weights to the split-half reliability based on trial numbers in each dataset is warranted. Using a method similar to weighted averaging, we derived the final effect size of the split-half reliability.

**Test-Retest Reliability (ICC).** We assessed the test-retest reliability of the six indices for our dataset that involved test-retest sessions by calculating the Intraclass Correlation Coefficient (ICC) using “psych” package (Revelle, 2017). ICC is a well-established measure used in test-retest, intra-rater, and inter-rater studies to assess reliability (Fisher, 1992). Unlike the Pearson correlation coefficient, ICC considers both the correlation and agreement between multiple measurements, making it a more comprehensive measure of test-retest reliability. Within the ICC family, we employed ICC2 and ICC2k. ICC2 focuses on the individual-level reliability of the indices, while ICC2k evaluates the reliability of mean ratings furnished by a group of judges (Koo & Li, 2016). The formula for ICC2 is:

where *MSBS* is the mean square between subjects, *MSE* is the mean square error, *MSBM* is the mean square between measurements, *k* is the number of measurements, n is number of participants. The formula for ICC2k is:

Although there is no strict criterion for defining the level of reliability, a widely accepted guideline for Cronbach’s alpha is that a value of 0.60 is “acceptable”, and a value greater than 0.8 means excellent reliability (Cicchetti & Sparrow, 1981; Kupper & Hafner, 1989).

# **3 Deviation from preregistration**

In our pre-registration plan, we intended to estimate the drift rate (*v*) and starting point (*z*) of the drift-diffusion model (DDM) using the “fit\_ezddm” function from the “hausekeep” package (Lin et al., 2020). This function was a wrapper for the EZ-DDM function (Wagenmakers et al., 2007). However, parameter recovery found that this algorithm did not perform well (see Supplementary Fig. 6). Thus, we used “RWiener” package (Wabersich & Vandekerckhove, 2014), which performed much better in parameter recovery (see Supplementary Fig. 6). Nevertheless, results from ezDDM can be found in supplementary materials.

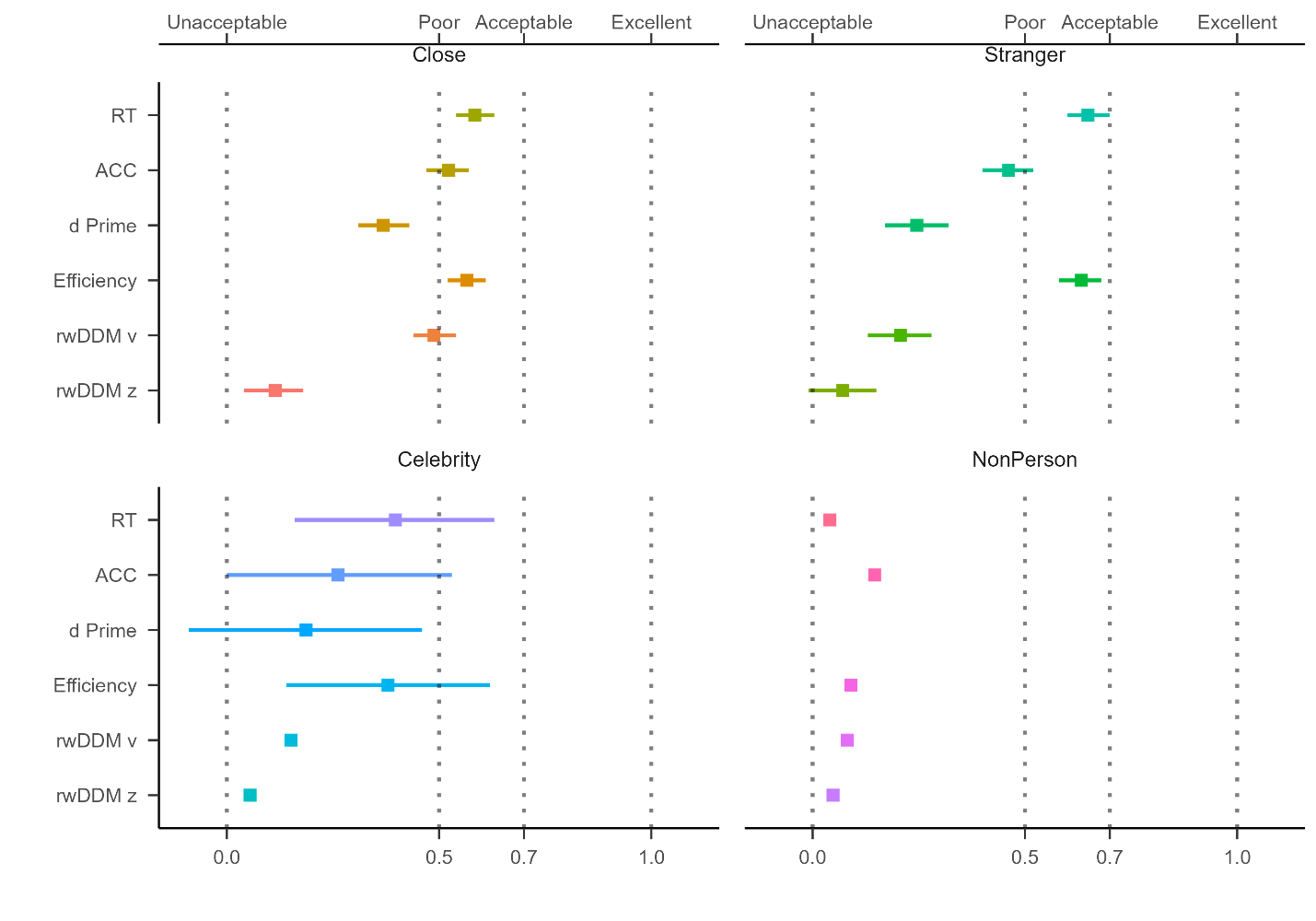
# **4 Results**

In 18 datasets, 14 datasets have data for the contrast Self vs Close other, 12 datasets have the data for Self vs Stranger, 2 datasets have the data for Self vs Celebrities, 1 dataset has the data for Self vs none condition. We reported the results for all these contrasts.

## 4.1 Split-Half Reliability

As described in method part, we utilized four different methods to calculate split-half reliability, namely the first-second, odd-even, permuted, and Monte Carlo methods. Here we reported the results from Monte Carlo split-half method because of its robustness (Pronk et al., 2022). The results of the other three split-half reliabilities can be found in the supplementary materials (see Supplementary Fig. 1 & 2). Here, we focused on discussing the results of Monte Carlo split-half reliabilities.

The vertical axis represents six different indices, and the horizontal axis represents the effect size of split-half reliability. As depicted in Fig. 3, the effect size of split-half reliability for "RT" and "Efficiency" is larger. In fact, the majority of datasets with a high number of trials (more than 60) achieved a split-half reliability of 0.6 or higher (see Supplementary Fig. 3), which is considered an acceptable level of reliability. After calculating the effect size from 14 datasets with "Self vs Close," the effect size for RT is 0.58, SE = 0.02, p <.001, 95% CI [.54, .63], and for Efficiency, it is 0.57, SE= 0.02, p <.001, 95% CI [.52, .61]. For the 12 datasets with "Self vs Stranger," the effect size for RT is 0.65, SE = 0.02, p <.001, 95% CI [.60, .70], and for Efficiency, it is 0.63, SE = 0.02, p <.001, 95% CI = [.58, .68]. Overall, for the remaining four indices, the effect sizes of "Accuracy" and "rwDDM v" are approximately 0.5, while the effect sizes of "*d’*" are around 0.4. However, the effect sizes of "rwDDM z" are almost 0. It is worth noting that, in the "Self vs Stranger" condition, the effect size of “rwDDM v" is much lower compared to the "Self vs Close" condition (0.21 vs. 0.49). In general, given a sufficient number of trials, RT and Efficiency may have good reliability, followed by ACC and "rwDDM v." “d’” may have relatively lower reliability, while "rwDDM z" can be considered to have no reliability.



**Fig. 3.** The effect size ofMonte-Carlo split-half reliabilities for different SPE indices.

RT: reaction times; ACC: accuracy; *d’*: sensitivity index in signal detection theory; Efficiency: ratio of mean reaction time to average accuracy in matching group, *v*: drift rate in drift diffusion model; *z*: starting point in drift diffusion model. The vertical axis represents six different indices, and the horizontal axis represents the effect size of split-half reliability. Each facet in the figure represents a different target for the Self-Prioritization Effect (SPE), namely close other, stranger, celebrity, and none. Each point represents the weighted average of split-half reliability (effect size) for all datasets under the corresponding target. The lines on either side of the point represent the 95% confidence interval for that point estimate. If only one point is shown in the graph, it indicates that the confidence interval for that point estimate extends beyond the range of our coordinate axes (0, 1).

## 4.2 Intraclass correlation coefficient (ICC)

It is important to note that we could only calculate ICC for our own data (Hu et al., 2023). Because all other datasets did not include re-test sessions. To test the robustness of the results reported here, we explored two datasets that included re-test session but devivated from the original SPMT (see Supplementary Fig. 4).

As shown in Fig. 4, The ICC2k values for RT and Efficiency are quite high, while other indices are quite low. When the target is "Close other," the ICC2k for RT is 0.87 (95%CI = [.79, .93]), and for Efficiency, it is 0.86 (95%CI = [.78, .93]). When the target is "Stranger," the ICC2k for RT is 0.89 (95%CI = [.82, .94]), and for Efficiency, it is 0.76 (95%CI = [.61, .87]). However, RT and Efficiency exhibit lower ICC2 values. When the target is "Close," the ICC2 for RT is 0.53 (95%CI = [.39, .69]), and for Efficiency, it is 0.52 (95%CI = [.38, .68]). When the target is "Stranger," the ICC2 for RT is 0.58 (95%CI = [.45, .73]), and for Efficiency, it is 0.34 (95%CI = [.21, .52]). This suggests that, at the individual level, the SPMT paradigm does not demonstrate a robust test-retest reliability. But, at the group level, this paradigm exhibits a high test-retest reliability.

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**Fig. 4** Intraclass correlation coefficient.

RT: reaction times; ACC: accuracy; *d’*: sensitivity index in signal detection theory; Efficiency: ratio of mean reaction time to average accuracy in matching group, *v*: drift rate in drift diffusion model; *z*: starting point in drift diffusion model. The vertical axis represents six different indices, and the horizontal axis represents the value of ICC. The first column represents the result for “Close”, and the second column represents the result for “Stranger”. The first row represents the results for ICC2, and the second row represents the results for ICC2k. Each point represents the point estimate of ICC. The lines on either side of the point represent the 95% confidence interval for that point estimate. If only one point is shown in the graph, it indicates that the confidence interval for that point estimate extends beyond the range of our coordinate axes (0, 1).

# **5 Discussion**

Evaluating the reliability of a behavioral paradigm is essential for researchers planning to use the paradigm to investigate different research questions, such as individual differences and underlying mechanisms. Despite its importance, this practice is not yet widely adopted among researchers (Green et al., 2016; Hedge et al., 2018; Parsons et al., 2019). In this pre-registered study, our objective is to investigate the reliability of the indices related to the self-prioritization effect (SPE) in the self-perceptual matching task (SPMT). To achieve this, we conducted a re-analysis of data from 18 datasets across 11 articles, utilizing split-half reliability and intraclass correlation coefficient (ICC2, ICC2k). Our findings reveal that all the indices performed poorly in terms of split-half reliability and individual-level test-retest reliability (ICC2), with reaction time (RT) and efficiency demonstrated better results. Conversely, the estimated ICC2 for the other four indices were below 0.5. Our analysis of these datasets collectively demonstrates that RT and efficiency are the most reliable indices in the SPMT while the SPMT is better suited for group-level analysis rather than assessing individual-level variation.

The low split-half reliability and low ICC2 may suggest that SPE effect is not suitable for assessing individual-level variation. Although the Reaction Time (RT) and Efficiency indices yielded relatively better results compared to other indices, they still fell short of achieving commonly considered excellent reliability levels (typically higher than 0.8 or even higher than 0.9) (Cicchetti & Sparrow, 1981; Kupper & Hafner, 1989). Several plausible reasons as well as potential solutions can be identified. Firstly, the insufficient number of trials per condition may contribute to the low split-half reliability. A recent study by Kucina et al. (2023) emphasized the importance of trial numbers for cognitive tasks in determining reliability. The findings revealed that increasing the number of trials and considering greater conflict effects or individual differences can enhance reliability compared to the original paradigm. Specifically, the study identified that satisfactory reliability required 48 or more trials, while achieving a higher level of reliability necessitated 72 trials. As shown in Supplementary Fig. 5, we calculated the correlation coefficient between the trial numbers and the corresponding Monte Carlo split-half reliabilities. We found a strong positive correlation between certain metrics, such as RT and Efficiency. Therefore, incorporating a higher number of trials in future implementations of the SPMT paradigm may enhance split-half reliability by improving measurement consistency. Secondly, the presence of a practice effect or fatigue effect could be another significant factor influencing reliability. If these effects are substantial enough to cause a noticeable change in participants' performance between measurement occasions, it can introduce additional variability in the measurements and lower the ICC2 values (Oswald et al., 2015; Siegelman et al., 2017). This highlights the need for a more nuanced task setting that can consistently capture performance nuances and reveal individual differences more sensitively (Hedge et al., 2018). Recent study on gamification of cognitive tasks have shown that incorporating gamification elements can effectively improve data quality and assessment efficacy (Friehs et al., 2020). Therefore, modifying the SPMT with a more dynamic paradigm, such as incorporating gamification elements, may enhance split-half reliability by improving measurement consistency. Finally, it is worth mentioning the influence of serial dependence effects on task reliability. A recent set of studies has examined serial dependence effects in a variety of cognitive tasks (Braun et al., 2018; Zhang & Alais, 2020). Serial dependence refers to the phenomenon in which the outcome of one trial is influenced by preceding trials, resulting in a systematic relationship between consecutive trials (Pascucci et al., 2023). Notably, studies in the field of perceptual decision making have demonstrated strong serial dependence effects in perception, even when the visual stimuli were reliable and varied randomly over time (Fischer & Whitney, 2014; John-Saaltink et al., 2016). In particular, if the split-half design unintentionally separates temporally adjacent trials in the SPMT, the presence of serial dependence may introduce performance differences between the halves, leading to a reduction in the reliability estimate. Thus, to accurately control for the impact of serial dependence in experiments, further research should employ appropriate statistical methods that account for the temporal dependencies between trials. Time series analysis techniques (Huitema, 1986) or modeling approaches that capture the serial correlation (Mei et al., 2023)can be utilized to obtain more accurate results.

We would like to emphasize the importance of considering the parameters derived from the drift diffusion model in the analysis of reaction time within the SPMT. Our findings indicate that the split-half reliability and test-retest reliability of the model parameters was notably low. This raises concerns about the suitability of applying the classic drift diffusion model in cognitive tasks like SPMT. Since the classic drift diffusion model relies on specific assumptions regarding the cognitive processes underlying reaction time (specifies fixed values for drift, bound height or noise level, starting position bias, and non-decision time) (Ratcliff, 1978; Ratcliff et al., 2016) , if these assumptions fail to accurately capture the true underlying mechanisms or if they are violated within the assumption of SPMT, it can result in inconsistent parameter estimates and diminished the reliability (Johnson et al., 2017). Thus, our results raise significant questions regarding the efficacy of applying the classical hierarchical drift diffusion model to the SPMT. Further research is needed to comprehensively investigate the underlying causes of low split-half reliability and test-retest reliability. Additionally, it is important to develop extensions to the drift diffusion model and explore alternative modeling approaches that can produce more reliable parameter estimates. Due to the methodological challenges involved in introducing innovations to the model, several researchers have proposed user-friendly frameworks for building and fitting extensions to the drift diffusion model. Examples include the generalized drift-diffusion model (GDDM) by Shinn et al. (2020), RLDDM modules in HDDM by Pedersen and Frank (2020). These extensions offer alternative modeling approaches that could be used to better capture the true underlying mechanisms of reaction time in SPMT. These efforts could contribute to the refinement and optimization of the model for future research applications, enabling more reliable and valid interpretations of cognitive processes in the SPMT and similar paradigms.

The results obtained from the intraclass correlation coefficients (ICCs) indicate that the SPMT, particularly the Response Time (RT) and efficiency measures, is more appropriate for group-level analysis rather than assessing individual-level variation. Specifically, we found that the RT and efficiency measures exhibited high test-retest reliability at the group level (ICC2k), indicating strong group-level consistency over time. For RT and Efficiency, regardless of whether the Target is “Close” or “Stranger”, ICC2k exceeded 0.85, except for Efficiency in the “Close” condition with an ICC2k of 0.76 (95% CI = [.61, .87]) which is still considered acceptable. On the other hand, the ICC2 values for RT and Efficiency were relatively low, below 0.5. This discrepancy suggests that the SPMT is more influenced by variations between participants rather than within participants. Similar results patterns have been observed in previous research examining other cognitive paradigms such as Flanker, Simon, or Stroop tasks (Clark et al., 2022; Mollon et al., 2017). These findings also align with the concept of the reliability paradox proposed previously (Hedge et al., 2018; Logie et al., 1996). Behavioral paradigms, including the SPMT, are susceptible to factors such as external conditions and contextual differences, which contribute to greater within-participant variability and lower ICC2 values. However, when averaging performance across different individuals, the task still demonstrates good consistency, leading to higher ICC2k values (Liljequist et al., 2019). It is important to note that ICC values should not be interpreted solely as a measure of the test's overall quality, but rather as an indication of the specific types of questions it can effectively address (Koo & Li, 2016). In practical terms, these results suggest that the SPMT is better suited for discerning performance differences between individuals or groups rather than capturing consistent performance within the same individuals over time. Therefore, researchers should consider these factors when investigating individual differences using the SPMT.

Our study has several limitations that should be acknowledged. Firstly, although we made efforts to enhance sample diversity by including open data whenever possible, it is important to note that the majority of our samples still consisted of individuals from what is commonly referred to as "wired" populations (Rad et al., 2018). As a result, our findings may not be fully representative of the broader population, and it is necessary to include a more diverse sample to ensure greater generalizability of the paradigm. Additionally, when assessing the intraclass correlation coefficients (ICCs), only our own dataset had longitudinal data available, which could potentially limit the representativeness of the results. Furthermore, the majority of the studies included in our analysis focused on adults from healthy populations. Therefore, further investigation is needed to include more datasets with a more diverse population in order to determine the reliability of the SPMT in different settings. Finally, it is important to clarify the aim of our study, which primarily focused on exploratory purposes and providing information regarding the current state of reliability for the assessed indices. Consequently, future research could concentrate on modifying the paradigm and conducting tests to assess potential improvements. We propose several approaches that could be considered, such as introducing more challenging task variations (gamification) that have the potential to increase the reliability of accuracy measurements. Another suggestion is to include a greater number of trials for each condition, as this may contribute to improved reliability. It is strongly encouraged to undertake further investigation and experimentation in order to refine the paradigm and enhance the reliability of the indices, rather than dismissing the paradigm under certain circumstances.

In conclusion, this study provides significant insights into the reliability of the self-perceptual matching task (SPMT) and highlights important considerations for interpreting its reliabilities. We have demonstrated that the Response Time (RT) and Efficiency measures exhibit greater reliability compared to other indices in the SPMT. Furthermore, our findings indicate that the SPMT is more suitable for group-level analysis rather than assessing individual-level variation. These findings have important implications for future task design and data collection protocols aimed at improving reliability. Ultimately, our study paves the way for the prospective utilization of these tasks, in various domains including research, clinical applications, and personal performance monitoring. The information obtained from our study contributes valuable knowledge to the field and sets the stage for further investigations and advancements in utilizing SPMT effectively.

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# **Author contributions**

HCP contributed to the conception and supervision of the study. JS contributed to fund raising, HCP contributed to data collection. ZL, ZYR and HMZ will perform the data pre-processing, analysis and visualize the results. In addition, ZL, JS, HMZ and HCP will contribute to discussing the results and the drafting of the final manuscript. All authors will critically revise the manuscript.

# **Data and Material Availability**

The pre-registration plan is available at <https://osf.io/zv628>. The de-identified raw data from our lab is available at <https://doi.org/10.57760/sciencedb.08117>. The simulated data is accessible on GitHub (<https://github.com/Chuan-Peng-Lab/ReliabilitySPE>).

# **Code Availability**

Code used to simulate and analyze the data is made accessible at <https://github.com/Chuan-Peng-Lab/ReliabilitySPE>.

# **Competing interests**

The authors declare no competing interests.

**Supplementary information**

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**Supplementary Fig. 1** Other 3Split-Half Reliabilities for different SPE indices

RT: reaction times; ACC: accuracy; *d’*: sensitivity index in signal detection theory; Efficiency: ratio of mean reaction time to average accuracy in matching group, *v*: drift rate in drift diffusion model; *z*: starting point in drift diffusion model. The vertical axis represents eight different indices, and the horizontal axis represents the effect size of split-half reliability. From left to right, the figure represents the split-half reliabilities calculated using three different methods: first-second, odd-even, and permuted. From top to bottom, each facet in the figure represents a different target for the Self-Prioritization Effect (SPE), namely friend, stranger, celebrity, and none. Each point represents the weighted average of split-half reliability (effect size) for all datasets under the corresponding target. The lines on either side of the point represent the 95% confidence interval for that point estimate. If only one point is shown in the graph, it indicates that the confidence interval for that point estimate extends beyond the range of our coordinate axes (0, 1).

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**Supplementary Fig. 2** Other 3Split-Half Reliabilities for different SPE indices

RT: reaction times; ACC: accuracy; *d’*: sensitivity index in signal detection theory; Efficiency: ratio of mean reaction time to average accuracy in matching group, *v*: drift rate in drift diffusion model; *z*: starting point in drift diffusion model. The vertical axis represents eight different indices, and the horizontal axis represents the split-half reliability. From left to right, the figure represents the split-half reliabilities calculated using three different methods: first-second, odd-even, and permuted. From top to bottom, each facet in the figure represents a different target for the Self-Prioritization Effect (SPE), namely friend, stranger, celebrity, and none.

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**Supplementary Fig. 3.** Monte Carlo Split-Half Reliabilities for different SPE indices.

RT: reaction times; ACC: accuracy; *d’*: sensitivity index in signal detection theory; Efficiency: ratio of mean reaction time to average accuracy in matching group, *v*: drift rate in drift diffusion model; *z*: starting point in drift diffusion model. From top to bottom, each color represents one of the 8 indices of SPE. From left to right, each facet in the figure represents a different target for the Self-Prioritization Effect (SPE), namely close other, stranger, celebrity, and none. Each point represents the Monte Carlo split-half reliability obtained from an individual dataset. The lines on either side of the point represent the 95% confidence interval for that point estimate. If only one point is shown in the graph, it indicates that the confidence interval for that point estimate extends beyond the range of our coordinate axes (0, 1).

Contrary to the main text, this figure also includes ezDDM (“hausekeep”), which also estimates drift rate (v) and starting point (z). Due to the assumption of z = a / 2 in hausekeep, its estimation of parameter a is highly inaccurate. Therefore, we did not report the results obtained from this package in the main text. From this graph, we can observe that ezDDM demonstrates higher stability in estimating the drift rate (v). It appears that the estimation method used in "hausekeep" relies on average reaction time and accuracy, while the estimation method in "RWiener" relies on individual trial-level reaction times and correctness. The chosen split-half procedure may have a greater impact on the estimation by "RWiener," leading to lower split-half reliabilities for both of its indices. This also suggests that the reliability of calculating DDM parameters through split-half reliabilities depends on two factors. Firstly, the stability of the parameter itself and secondly, the stability of the package used to compute that parameter. It is also possible that DDM itself may not be suitable for estimating the SPMT paradigm. It is possible that in the future, DDM variants specifically tailored for the SPMT paradigm might be needed.

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**Supplementary Fig. 4** Intraclass correlation coefficient for different SPE indices.

RT: reaction times; ACC: accuracy; *d’*: sensitivity index in signal detection theory; Efficiency: ratio of mean reaction time to average accuracy in matching group, *v*: drift rate in drift diffusion model; *z*: starting point in drift diffusion model. The vertical axis represents eight different indices, and the horizontal axis represents the value of ICC. The first column represents the result for “Close”, the second column represents the result for “Stranger” and the third column represents the result for “Celebrity”. The first row represents the results for ICC2, and the second row represents the results for ICC2k. Each point represents the point estimate of ICC. The lines on either side of the point represent the 95% confidence interval for that point estimate. If only one point is shown in the graph, it indicates that the confidence interval for that point estimate extends beyond the range of our coordinate axes (0, 1).

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**Supplementary Fig. 5** The regression between Monte Carlo split half reliability and trial numbers in the experiment for different SPE indices.

RT: reaction times; ACC: accuracy; *d’*: sensitivity index in signal detection theory; Efficiency: ratio of mean reaction time to average accuracy in matching group, *v*: drift rate in drift diffusion model; *z*: starting point in drift diffusion model. The vertical axis represents Monte-Carlo split-half reliability, and the horizontal axis represents the number of trials. Each facet represents one of eight SPE indices.

Some indices, such as RT, Efficiency, trial numbers and Monte Carlo split-half reliability are highly correlated. Other indices, such as d prime, drift rate (*v*), there is almost no correlation between trial numbers and split-half reliability. For the SPMT paradigm, it takes about 80 trials to achieve a Monte Carlo split-half reliability of 0.8 when the target is ‘Stranger’, and about 120 trials when the target is ‘Close’. The drift rate (*v*) of may also achieve a Monte Carlo split-half reliability of 0.8 with more than 130 trials. It is difficult to achieve high Monte Carlo split-half reliability for the other three indices, especially for the starting point (z) of DDM, even if the number of trials increases to 150 or higher.

It must be emphasized that we only conducted a simple regression analysis of the trial numbers and Monte Carlo split-half reliability based on the datasets we collected. As can be seen from the graph, when the target is set to ‘Stranger’, there is actually no study that has more than 60 trials, so our inference about the trial numbers may be inaccurate. However, given the high correlation between the number of trials and Monte Carlo split-half reliability, we believe that for the SPMT paradigm, if higher reliability is desired for personal trait assessment or clinical evaluation, more trials are needed. It may be reasonable to have more than 120 trials under each experimental condition.

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**Supplementary Fig. 6 DDM Packages Comparison**

a: threshold parameter; t: non-decision time; v: drift rate; z: starting point. The y-axis represents three different R packages for estimating DDM parameters: “RWiener”, “hausekeep”, and “FastDMinR”. There are a total of five methods for estimating DDM parameters (3 method in FastDMinR). The x-axis represents the values of the estimated parameters. The dashed line represents the true value of the parameter.

We generated 100 datasets using the DDM package HDDM in Python. These datasets were set with parameters a=2, t=0.3, v=1, and z=0.7. Therefore, if the values obtained from the computation using the three DDM packages in R Package are closer to our set values, it indicates that the package provides more accurate parameter estimation.

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