



Original Article

## Minimum detectable change in reaction time to the Posner task due to change in sustained attention

KAZUYA AKIYAMA, RPT<sup>1)\*</sup>, SHINTA TAKEUCHI, RPT, PhD<sup>2)</sup>, YUKIKO MAKIHARA, RPT, PhD<sup>2)</sup>, YUSUKE NISHIDA, RPT, PhD<sup>1, 2)</sup>

<sup>1)</sup> Department of Rehabilitation Medicine, International University of Health and Welfare Narita Hospital: 852 Hatakeda, Narita, Chiba 286-8520, Japan

<sup>2)</sup> Department of Physical Therapy, School of Health Sciences at Narita, International University of Health and Welfare, Japan

**Abstract.** [Purpose] Spatial attention evaluations are beneficial for patients with unilateral spatial neglect or dementia. Thus, such evaluations are crucial among these patients for determining functional disorder extents. The study aimed to determine minimal detectable changes in reaction time to the Posner task among healthy young participants for establishing spatial attention evaluation protocols. [Participants and Methods] The study recruited 10 healthy young adults (five males and five females; mean age:  $28.9 \pm 4.0$  years). Each participant completed two sessions of the Posner task with 160 trials per session. The reaction time for each trial was measured. Data obtained by the two blocks were analyzed by Bland–Altman analysis, and intraclass correlation coefficient case 1 and minimal detectable changes at the 95% confidence interval were calculated. [Results] Bland–Altman analysis indicated no systematic bias. The intraclass correlation coefficient case 1 exceeded 0.80 under all conditions of the Posner task, whereas the minimal detectable changes at the 95% confidence interval spanned 23–34 ms. [Conclusion] The results exhibited high reliability for reaction time to the Posner task. The minimal detectable changes as the 95% confidence interval values determined in this study based on reaction time can be applied to establish spatial attention evaluation protocols.

**Key words:** Spatial attention, Posner task, Reliability

(This article was submitted Nov. 9, 2021, and was accepted Jan. 1, 2022)

### INTRODUCTION

Attention denotes the selection of the most relevant stimuli in the physical world to achieve behavioural goals efficiently<sup>1)</sup>. Specifically, spatial attention is defined as the ability to extract information from regions of space<sup>2)</sup>. Previous studies<sup>3, 4)</sup> suggest that evaluating spatial attention is beneficial for patients with unilateral spatial neglect or dementia. Spatial attention can be categorized into two distinct mechanisms, namely, bottom-up and top-down attentions. Bottom-up attention refers to attentional guidance to stimuli by externally driven factors. Such stimuli are typically salient in the environment due to their inherent properties relative to the background. On the other hand, top-down attention pertains to the internal guidance of attention based on prior knowledge, determined plans and current goals.

The Posner task is considered the ‘gold standard’ for the evaluation of spatial attention<sup>5, 6)</sup>. However, scholars report that its reliability is low in experimental approaches<sup>7, 8)</sup>. This reliability problem may arise from the implicit assumption that the experimental task is robust and therefore task performance is an objective measure<sup>7)</sup>. Therefore, clarifying the reliability of the Posner task is necessary for establishing a method of evaluating spatial attention.

\*Corresponding author. Kazuya Akiyama (E-mail: 20s3004@g.iuhw.ac.jp)

©2022 The Society of Physical Therapy Science. Published by IPEC Inc.



This is an open-access article distributed under the terms of the Creative Commons Attribution Non-Commercial No Derivatives (by-nc-nd) License. (CC-BY-NC-ND 4.0: <https://creativecommons.org/licenses/by-nc-nd/4.0/>)

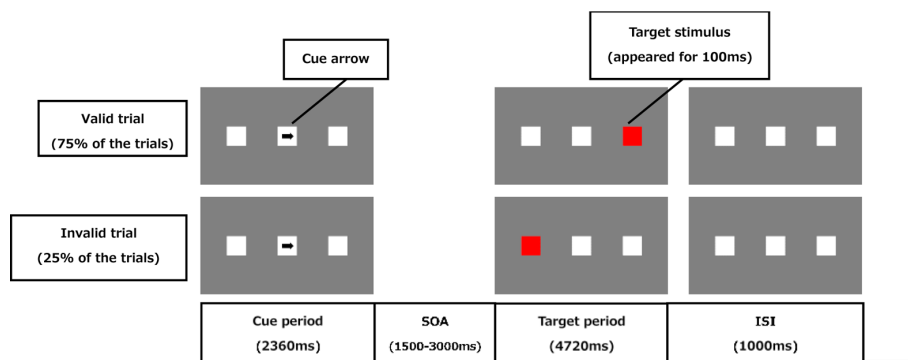
The literature provides two approaches for investigating reliability, namely, the approaches for relative and absolute reliability<sup>9, 10</sup>. Absolute reliability refers to the type and amount of errors in measured values, where Bland–Altman analysis<sup>11</sup> and minimum detectable change (MDC)<sup>12</sup> are used as a method of investigation. Bland–Altman analysis is used to investigate systematic bias, whereas MDC investigates the amount of measurement error<sup>10</sup>. Several researchers employ MDC, analysing a 95% confidence interval (MDC95) as a measure of absolute reliability<sup>12</sup>. On the other hand, relative reliability represents test-retest reliability, which employs the intraclass correlation coefficient (ICC)<sup>7</sup>. In terms of relative reliability, the ICCs of reaction times (RTs) to the Posner task that are considered valid and invalid are reported at >0.80 and >0.70, respectively, in healthy young participants<sup>7</sup>. However, there is no report on MDC, which is a measurement of the absolute reliability.

In addition, patients with unilateral spatial neglect may display less reliability in terms of RT due to non-spatial lateralised deficits, such as sustained attention<sup>13</sup>, which is influenced by an increase in the number of trials in the Posner task. In clinical applications, we are considering using the Posner task to determine the rehabilitation effects for patients with unilateral spatial neglect, or the preventive effects against a cognitive decline in the elderly participants. In these cases, we think that the MDC value of the Posner task RT could be used as a clear indication that shows there are changes which are more than a measurement error when judging the effects. We understand that it will be required to clarify the value of MDC in patients with unilateral spatial neglect and elderly participants, but as a basic knowledge, we propose that the value of MDC should be identified in healthy young participants because they are considered to have the least amount of variation in the reaction time. Therefore, defining MDC95 values of RTs under the conditions of the Posner task is necessary before we apply the Posner task to patients with unilateral spatial neglect. For this reason, we aimed to determine the MDCs of RTs for healthy young participants to establish protocols for evaluating spatial attention.

## PARTICIPANTS AND METHODS

The participants were 10 healthy young adults (five males and five females, age: mean  $\pm$  SD: 28.9  $\pm$  4.0 years) who are right-handed and without history of diseases related to the central nervous system. The researchers presented exhaustive explanations of all procedures and potential risks, after which the participants provided informed consent. The Ethics Committee of the International University of Health and Welfare approved the study (reference number: 18-Io-137).

PsychoPy is used to generate stimuli, which were displayed on a laptop computer (Dell, Round Rock, TX, USA, 1,920  $\times$  1,080 pixels). **Figure 1** illustrates the protocols of the Posner task as used in the study. At the beginning of a trial, a central fixation spot (square) and square boxes located to the left and right sides of the central fixation were displayed. The boxes were placed at a visual angle of 3.3° to either side of the fixation spot. A cue arrow pointing to the left or right box was superimposed on the fixation spot for a period of 2,360 ms. Leftward or rightward arrows were equally probable. After a stimulus onset asynchrony (SOA) of between 1,500 and 3,000 ms was randomly selected, a 100-ms target stimulus (turns red) was flashed in the box. In valid (75%) and invalid (25%) trials, a target appeared at cued and uncued locations, respectively. After detecting the target or after 4,720 ms from the presentation of the target stimulus, the next trial was started with an interstimulus interval of 1,000 ms. The total number of trials was 160, and trial conditions (i.e. valid and invalid  $\times$  right and left) were randomly intermixed. Each participant completed two sessions. The participants were seated on a chair in front of



**Fig. 1.** The protocols of the Posner task. The central fixation spot (square) and the square boxes located to the left and right of the central fixation were displayed at the beginning of each trial. The boxes were placed at a 3.3° of visual angle to either side of the fixation spot. At the beginning of each trial, a cue arrow pointing to the left or right box was superimposed on the fixation spot for a period of 2,360 ms. Leftward or rightward arrows were equally probable. After a randomly selected Stimulus onset asynchrony (SOA) between 1,500–3,000 ms, a 100 ms target stimulus (turns red) was flashed in the box. On a valid trial (75% of the trials), a target appeared at the cued location. On an invalid trial (25% of the trials), a target appeared at the uncued location. After detection of the target stimulus or after 4,720 ms from the target stimulus presentation, the next trial was started in an interstimulus interval (ISI) of 1,000 ms. Sessions contained 160 trials, and trial types (valid, invalid) were randomly intermixed.

a computer display from a distance of 60 cm and were instructed to respond as quickly as possible using the space bar upon detection of the target. The participants were also instructed to maintain their gazes on the central fixation. Previous studies<sup>14)</sup> have shown that the lower limit of RT is approximately 100 ms, and setting the criterion at three times of SD is reported to have little effect on outlier removal. RTs faster than 100 ms and slower than three times of each individual's average RT were excluded from the calculation of mean RTs. Then, the average value after excluding outliers was used as the representative value for each participant. Data were analysed using the Shapiro–Wilk test, Bland–Altman analysis, and case 1 of ICCs (ICC case 1). Furthermore, MDC at 95% confidence interval (MDC95) was calculated.

For Bland–Altman analysis, a 95% CI for the mean difference that excludes 0 was considered fixed bias. If the slope of the regression of mean differences differs significantly, then it was considered proportional bias<sup>15)</sup>. MDC95 was calculated using the standard deviation of the difference between each pair of values (SDd)<sup>12)</sup> as follows:

$$\text{MDC95} = 1.96 \times \text{SDd}. \text{ Eq. (1)}$$

ICCs between 0.00 and 0.20, between 0.21 and 0.40, between 0.41 and 0.60, between 0.61 and 0.80 and between 0.80 and 1.00 are considered ‘poor’, ‘fair’, ‘moderate’, ‘substantial’ and ‘nearly perfect’, respectively<sup>16)</sup>.

## RESULTS

Table 1 shows the results of RTs, Bland–Altman analysis, ICC case 1 and MDC95. Figure 2 plots the Bland–Altman plot. The results indicate that the average RTs were 334 to 340 ms for valid trials and 349 to 357 ms for invalid trials. The Shapiro–Wilk test indicated normality for all conditions ( $p \geq 0.05$ ).

For Bland–Altman analysis, the 95% CI for the mean difference included 0, whereas the slope of regression of mean differences was not significant under all conditions.

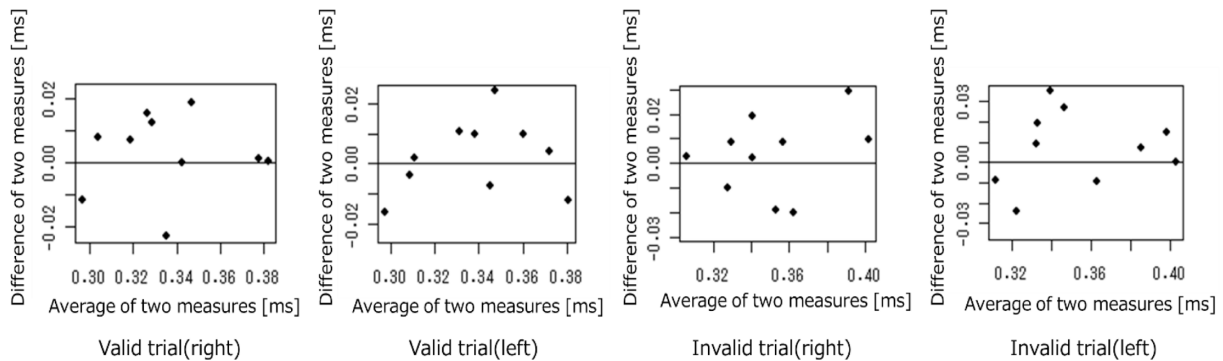
ICC case 1 reached more than 0.80 under all conditions.

MDC95 was 23–34 ms for each condition.

**Table 1.** Results of the reaction time (in ms), Bland–Altman analysis, ICC case 1, and MDC95 (in ms) under each condition

	Reaction time		Bland–Altman analysis			ICC (1,1)	MDC95
	(mean ± SD)		Fixed bias 95% confidence interval	Proportional bias			
	Block 1	Block 2		Slope of the regression of differences			
Valid trial (right)	337 ± 27	334 ± 27	−6.17–12.01	0.04	p=0.91	0.91	24
Valid trial (left)	340 ± 28	338 ± 26	−6.63–10.79	0.20	p=0.57	0.91	23
Invalid trial (right)	352 ± 30	349 ± 26	−8.07–14.51	0.27	p=0.45	0.87	29
Invalid trial (left)	357 ± 33	350 ± 31	−5.92–19.89	0.12	p=0.74	0.85	34

ICC: intraclass correlation coefficients; MDC95: minimal detectable change at 95% confidence interval.



**Fig. 2.** Bland–Altman plot of each condition. For Bland–Altman analysis, the 95% CI for the mean difference included 0, and the slope of the regression of mean differences was not significant in all conditions.

## DISCUSSION

Evaluating spatial attention is beneficial for patients with unilateral spatial neglect or dementia. The Posner task is a method to quantify the spatial attention by a RT<sup>6)</sup>. There are three types of RT, simple RT, discrimination RT, and choice RT, and the RT of the Posner task is classified as simple RT. The following factors have been reported as determinants of the simple RT: type of sensation, stimulus intensity<sup>17)</sup>, type of response action<sup>18)</sup>, effect of warning signal<sup>19, 20)</sup>, and anticipation of stimulus appearance<sup>21, 22)</sup>. In this study, the evaluation protocol was established by referring to the method of Corbetta et al.<sup>23)</sup> in which brain activity during the Posner task in healthy participants has been studied in detail.

The results indicate that the average RTs ranged from 334 to 340 ms and from 349 to 357 ms for valid and invalid trials. Previous studies report that RTs to the Posner task among healthy young participants ranges from 304 to 380 ms and from 310 to 426 ms for valid and invalid trials, respectively<sup>7, 23, 24)</sup>. In the current study, the average RT lies within the abovementioned ranges. Therefore, the setting for the Posner task adopted in this study is considered appropriate.

For Bland–Altman analysis, the 95% CI for the mean difference included 0, which indicates the absence of fixed bias. Moreover, the slope of regression of mean differences was not significant under all conditions, which points to the lack of proportional bias. Thus, systematic bias does not exist. Learning effect shortens RT<sup>25)</sup>, and fixed bias due to the learning effect is considered to lessen the reliability of RT. Based on the three principles of Fisher<sup>26)</sup>, randomisation converts systematic bias into random errors. Toward this end, the current study randomises the trial types and SOA in the Posner task. Therefore, systematic bias is not recognised.

ICC case 1 reach  $>0.80$  under all conditions. ICCs between 0.81 and 1.00 are ‘nearly perfect’. The results indicate high reliability in terms of RT in the Posner task. ICCs for RTs in valid and invalid trials are reported at  $>0.80$  and  $>0.70$ , respectively<sup>7)</sup>. Previous studies stated that intra-individual variability in RTs decreases between the ages of 18 and 29 years<sup>27)</sup>. Thus, the findings of the present study are in line with those of previous studies.

MDC95 for each condition is 23–34 ms, which elucidates the amount of measurement error.

In Eq. (1), MDC95 increases with the increase in the variability of RTs in each session. Thus, MDC95 is necessary for determining changes in measurement error. We have determined the value of MDC in healthy young participants. In this manner, the results serve as a basis for establishing protocols for evaluating spatial attention.

A limitation of the study is the small sample size. In future, we hope to obtain more favorable results from a larger sample and other age groups and populations to add to the generalizability of the results.

Another limitation was that the participants were healthy and young. Therefore, the results may be inapplicable to healthy elderly and patients with unilateral spatial neglect.

Future studies on healthy elderly participants and patients with unilateral spatial neglect are necessary based on the result of the current study.

### *Conflicts of interest*

The authors report no conflict of interest.

## REFERENCES

- 1) Katsuki F, Constantinidis C: Bottom-up and top-down attention: different processes and overlapping neural systems. *Neuroscientist*, 2014, 20: 509–521. [[Medline](#)] [[CrossRef](#)]
- 2) Shomstein S, Gottlieb J: Spatial and non-spatial aspects of visual attention: interactive cognitive mechanisms and neural underpinnings. *Neuropsychologia*, 2016, 92: 9–19. [[Medline](#)] [[CrossRef](#)]
- 3) Corbetta M, Kincade MJ, Lewis C, et al.: Neural basis and recovery of spatial attention deficits in spatial neglect. *Nat Neurosci*, 2005, 8: 1603–1610. [[Medline](#)] [[CrossRef](#)]
- 4) Karssemeijer EG, Aaronson JA, Bossers WJ, et al.: Positive effects of combined cognitive and physical exercise training on cognitive function in older adults with mild cognitive impairment or dementia: a meta-analysis. *Ageing Res Rev*, 2017, 40: 75–83. [[Medline](#)] [[CrossRef](#)]
- 5) Feher da Silva C, Baldo MV: Computational models of the Posner simple and choice reaction time tasks. *Front Comput Neurosci*, 2015, 9: 81. [[Medline](#)] [[Cross-Ref](#)]
- 6) Posner MI: Orienting of attention. *Q J Exp Psychol*, 1980, 32: 3–25. [[Medline](#)] [[CrossRef](#)]
- 7) Hedge C, Powell G, Sumner P: The reliability paradox: why robust cognitive tasks do not produce reliable individual differences. *Behav Res Methods*, 2018, 50: 1166–1186. [[Medline](#)] [[CrossRef](#)]
- 8) Ross DA, Richler JJ, Gauthier I: Reliability of composite-task measurements of holistic face processing. *Behav Res Methods*, 2015, 47: 736–743. [[Medline](#)] [[CrossRef](#)]
- 9) Furgal KE, Norris ES, Young SN, et al.: Relative and absolute reliability of the professionalism in physical therapy core values self-assessment tool. *J Allied Health*, 2018, 47: e45–e48. [[Medline](#)]
- 10) Rasmussen GH, Kristiansen M, Arroyo-Morales M, et al.: Absolute and relative reliability of pain sensitivity and functional outcomes of the affected shoulder among women with pain after breast cancer treatment. *PLoS One*, 2020, 15: e0234118. [[Medline](#)] [[CrossRef](#)]
- 11) Bland JM, Altman DG: Statistical methods for assessing agreement between two methods of clinical measurement. *Lancet*, 1986, 1: 307–310. [[Medline](#)]

[CrossRef]

- 12) Faber MJ, Bosscher RJ, van Wieringen PC: Clinimetric properties of the performance-oriented mobility assessment. *Phys Ther*, 2006, 86: 944–954. [Medline] [CrossRef]
- 13) Husain M, Rorden C: Non-spatially lateralized mechanisms in hemispatial neglect. *Nat Rev Neurosci*, 2003, 4: 26–36. [Medline] [CrossRef]
- 14) Miller J: Reaction time analysis with outlier exclusion: bias varies with sample size. *Q J Exp Psychol A*, 1991, 43: 907–912. [Medline] [CrossRef]
- 15) Ludbrook J: Statistical techniques for comparing measurers and methods of measurement: a critical review. *Clin Exp Pharmacol Physiol*, 2002, 29: 527–536. [Medline] [CrossRef]
- 16) Landis JR, Koch GG: The measurement of observer agreement for categorical data. *Biometrics*, 1977, 33: 159–174. [Medline] [CrossRef]
- 17) Kohfeld DL: Simple reaction time as a function of stimulus intensity in decibels of light and sound. *J Exp Psychol*, 1971, 88: 251–257. [Medline] [CrossRef]
- 18) Teichner WH, Krebs MJ: Laws of the simple visual reaction time. *Psychol Rev*, 1972, 79: 344–358. [Medline] [CrossRef]
- 19) Botwinick J, Brinley JF: An analysis of set in relation to reaction time. *J Exp Psychol*, 1962, 63: 568–574. [Medline] [CrossRef]
- 20) Mo Suchoon S, George Edward J: Foreperiod effect on time estimation and simple reaction time. *Acta Psychol (Amst)*, 1977, 41: 47–59. [CrossRef]
- 21) Karlin L: Reaction time as a function of foreperiod duration and variability. *J Exp Psychol*, 1959, 58: 185–191. [Medline] [CrossRef]
- 22) Drazin DH: Effects of foreperiod, foreperiod variability, and probability of stimulus occurrence on simple reaction time. *J Exp Psychol*, 1961, 62: 43–50. [Medline] [CrossRef]
- 23) Corbetta M, Kincade JM, Ollinger JM, et al.: Voluntary orienting is dissociated from target detection in human posterior parietal cortex. *Nat Neurosci*, 2000, 3: 292–297. [Medline] [CrossRef]
- 24) Greenwood PM, Parasuraman R, Haxby JV: Changes in visuospatial attention over the adult lifespan. *Neuropsychologia*, 1993, 31: 471–485. [Medline] [Cross-Ref]
- 25) Niemi P, Näätänen R: Foreperiod and simple reaction time. *Psychol Bull*, 1981, 89: 133–162. [CrossRef]
- 26) Fisher RA: Design of experiments. *BMJ*, 1936, 1: 554. [CrossRef]
- 27) Williams BR, Hultsch DF, Strauss EH, et al.: Inconsistency in reaction time across the life span. *Neuropsychology*, 2005, 19: 88–96. [Medline] [CrossRef]